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Kuwabara et al.

(10) **Patent No.: US 10,586,817 B2**
(45) **Date of Patent: Mar. 10, 2020**

(54) **SEMICONDUCTOR DEVICE, MANUFACTURING METHOD THEREOF, AND SEPARATION APPARATUS**

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(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 194 days.

(21) Appl. No.: **15/463,487**

(22) Filed: **Mar. 20, 2017**

(65) **Prior Publication Data**

US 2017/0278878 A1 Sep. 28, 2017

(30) **Foreign Application Priority Data**

Mar. 24, 2016 (JP) 2016-059492

(51) **Int. Cl.**
H01L 21/00 (2006.01)
H01L 27/12 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 27/1266*** (2013.01); ***H01L 21/67092*** (2013.01); ***H01L 21/67115*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01L 27/1266; H01L 27/1218; H01L 21/67092; H01L 21/6835; H01L 21/67115; H01L 2221/68395; H01L 2221/6835
(Continued)

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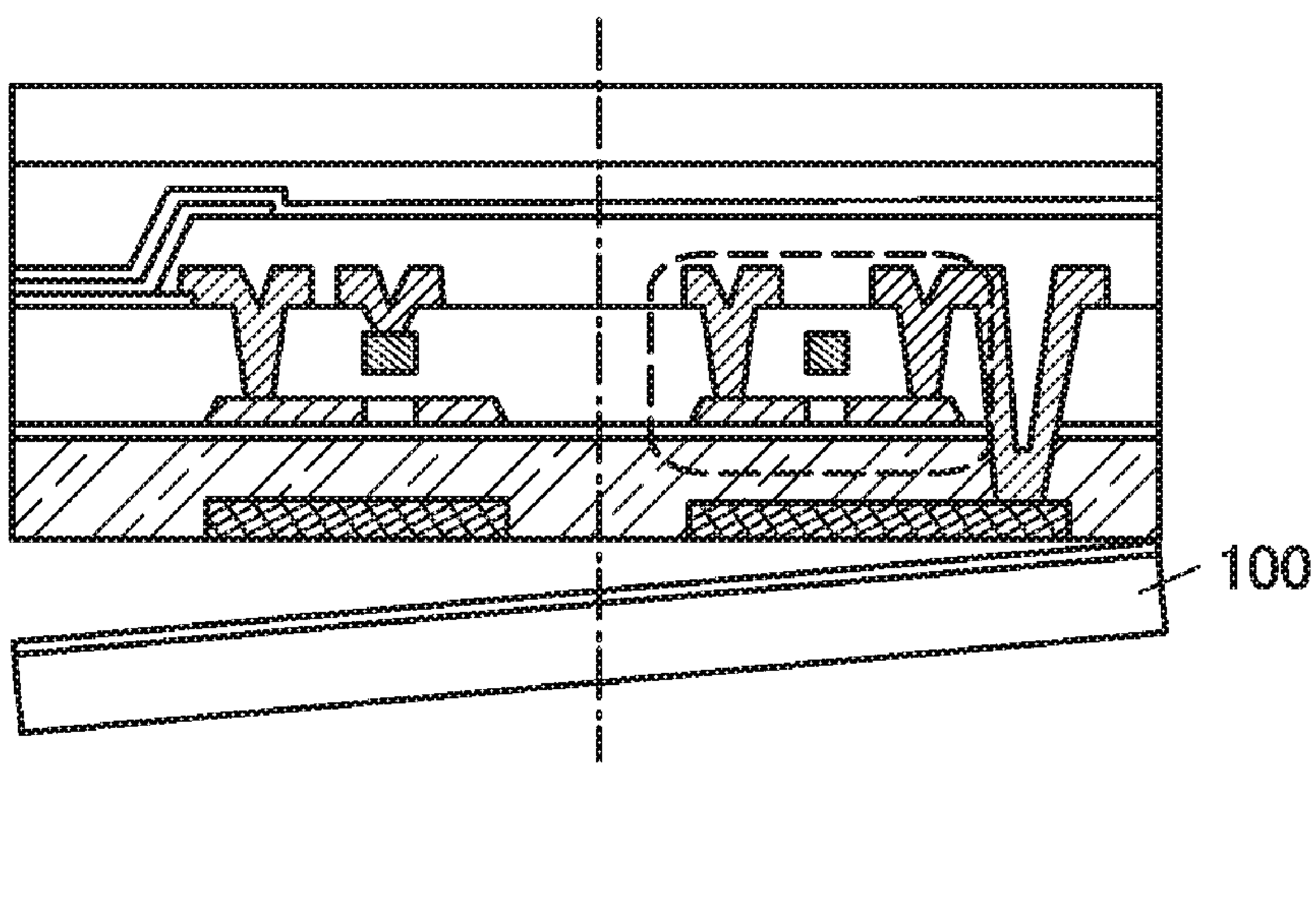
Primary Examiner — Vu A Vu
(74) *Attorney, Agent, or Firm* — Robinson Intellectual Property Law Office; Eric J. Robinson

(57) **ABSTRACT**

A technique is described in which a transistor formed using an oxide semiconductor film, a transistor formed using a polysilicon film, a transistor formed using an amorphous silicon film or the like, a transistor formed using an organic semiconductor film, a light-emitting element, or a passive element is separated from a glass substrate by light or heat. An oxide layer is formed over a light-transmitting substrate, a metal layer is selectively formed over the oxide layer, a resin layer is formed over the metal layer, an element layer is formed over the resin layer, a flexible film is fixed to the element layer, the resin layer and the metal layer are irradiated with light through the light-transmitting substrate, the light-transmitting substrate is separated, and a bottom surface of the metal layer is made bare.

13 Claims, 18 Drawing Sheets



(51) **Int. Cl.**
H01L 21/67 (2006.01)
H01L 21/683 (2006.01)

(52) **U.S. Cl.**
CPC .. ***H01L 21/6835*** (2013.01); *H01L 2221/6835* (2013.01); *H01L 2221/68395* (2013.01)

(58) **Field of Classification Search**
USPC 438/795
See application file for complete search history.

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FIG. 1A

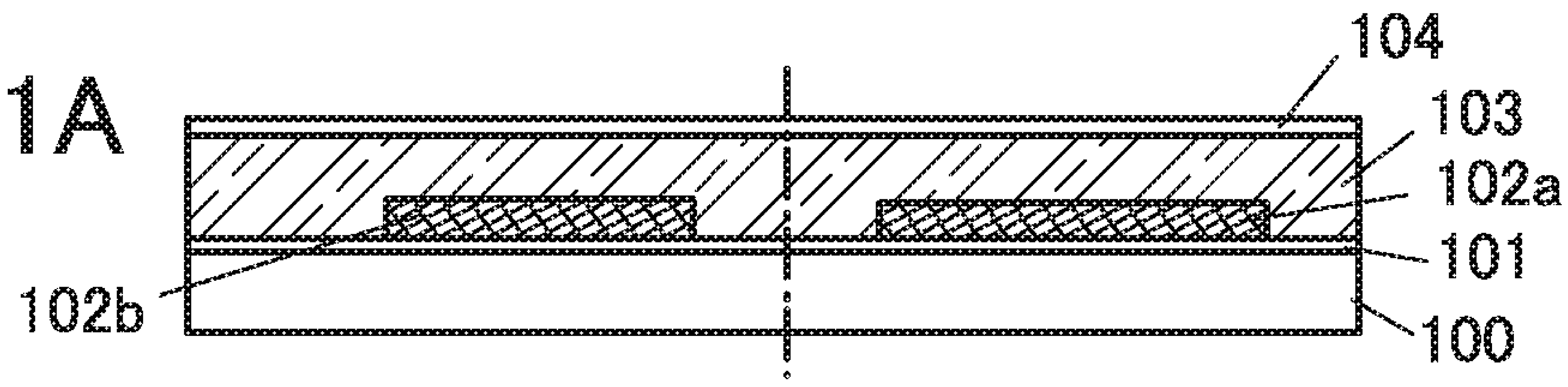


FIG. 1B

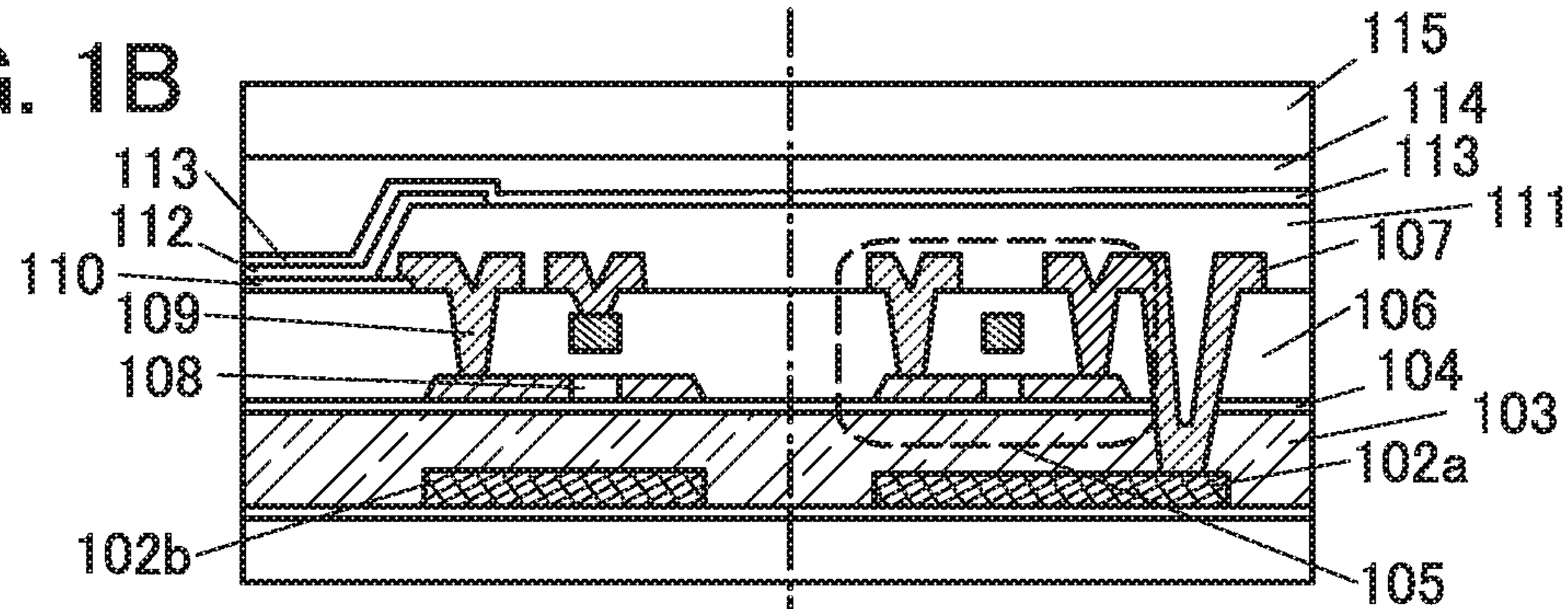


FIG. 1C

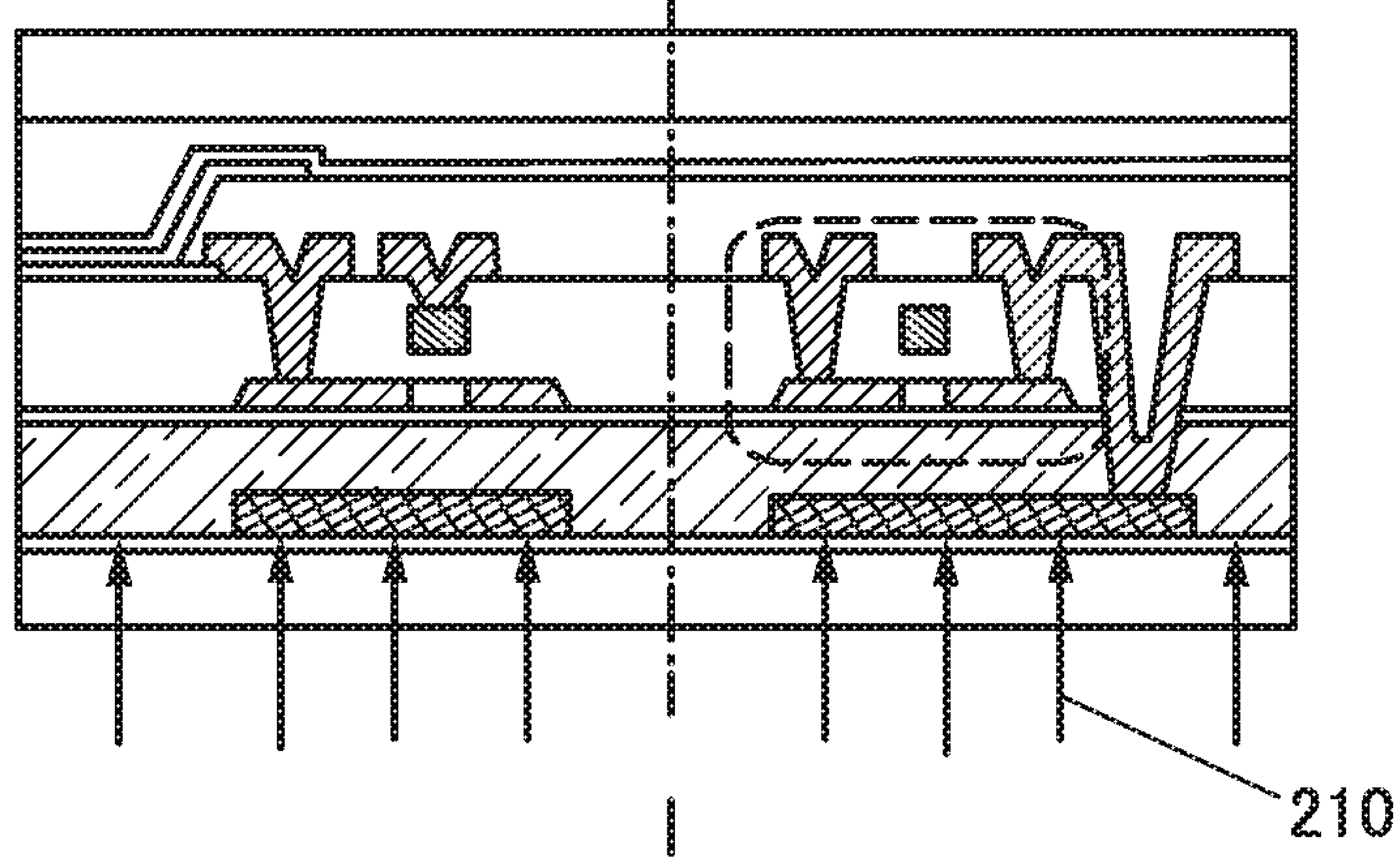


FIG. 1D

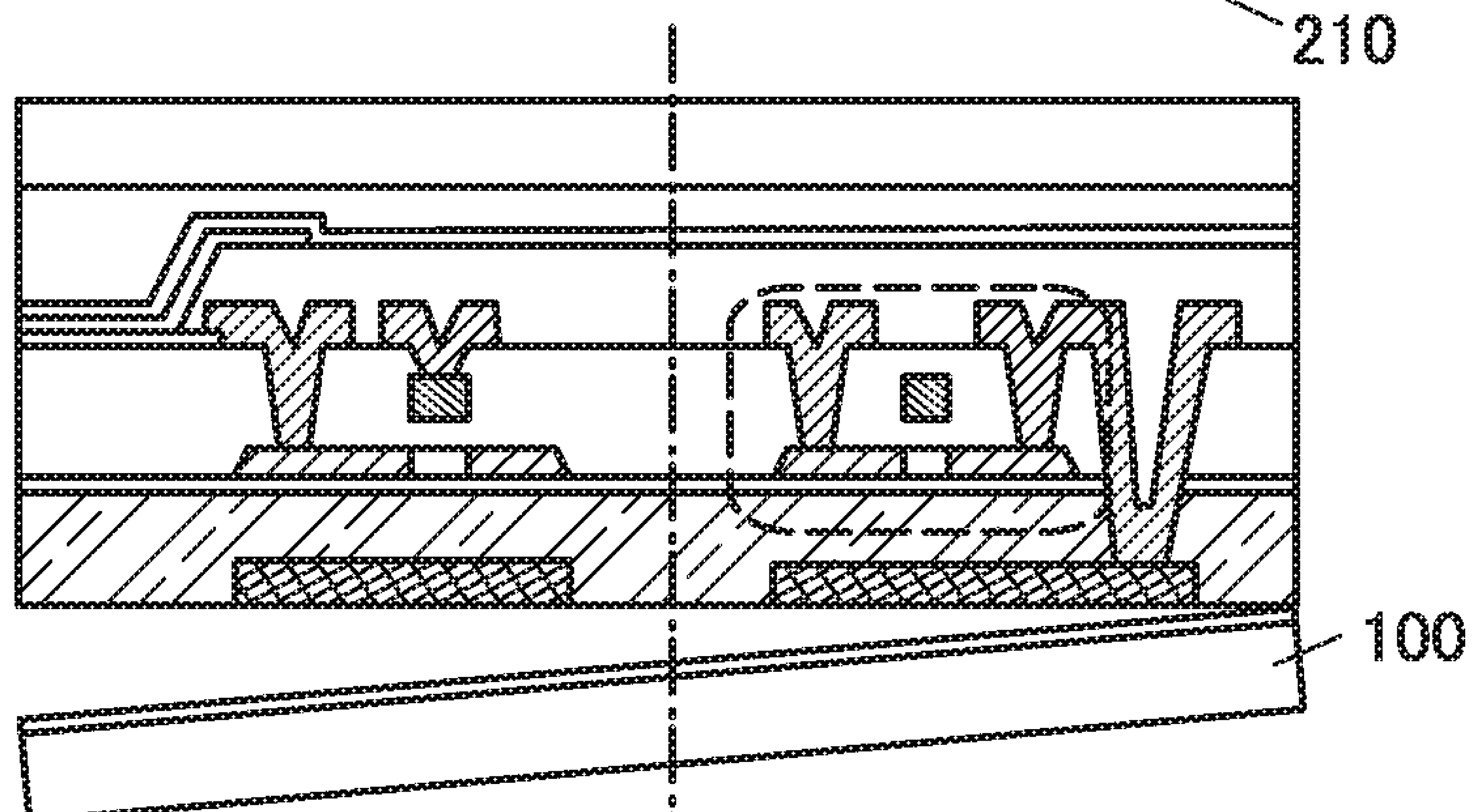


FIG. 1E

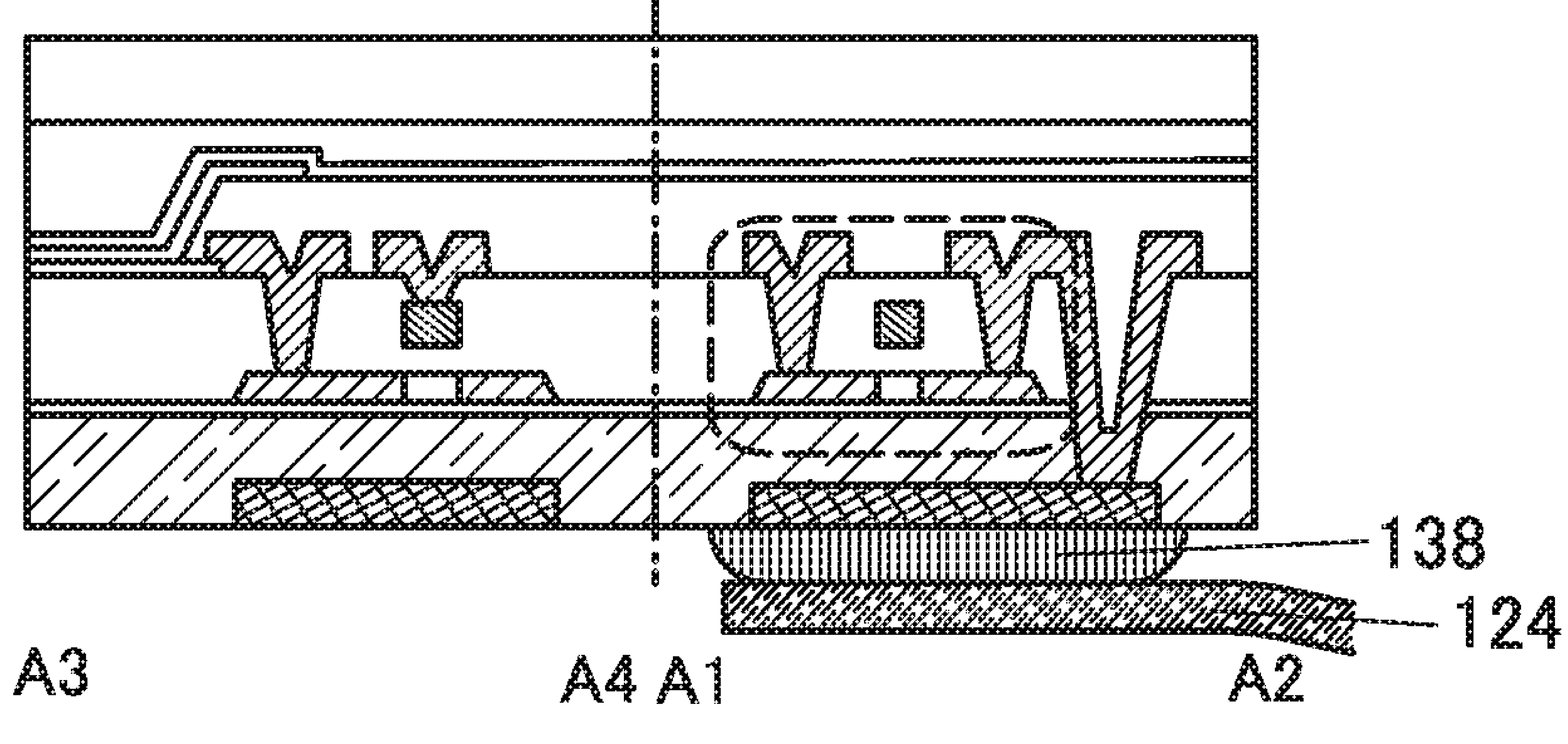


FIG. 2

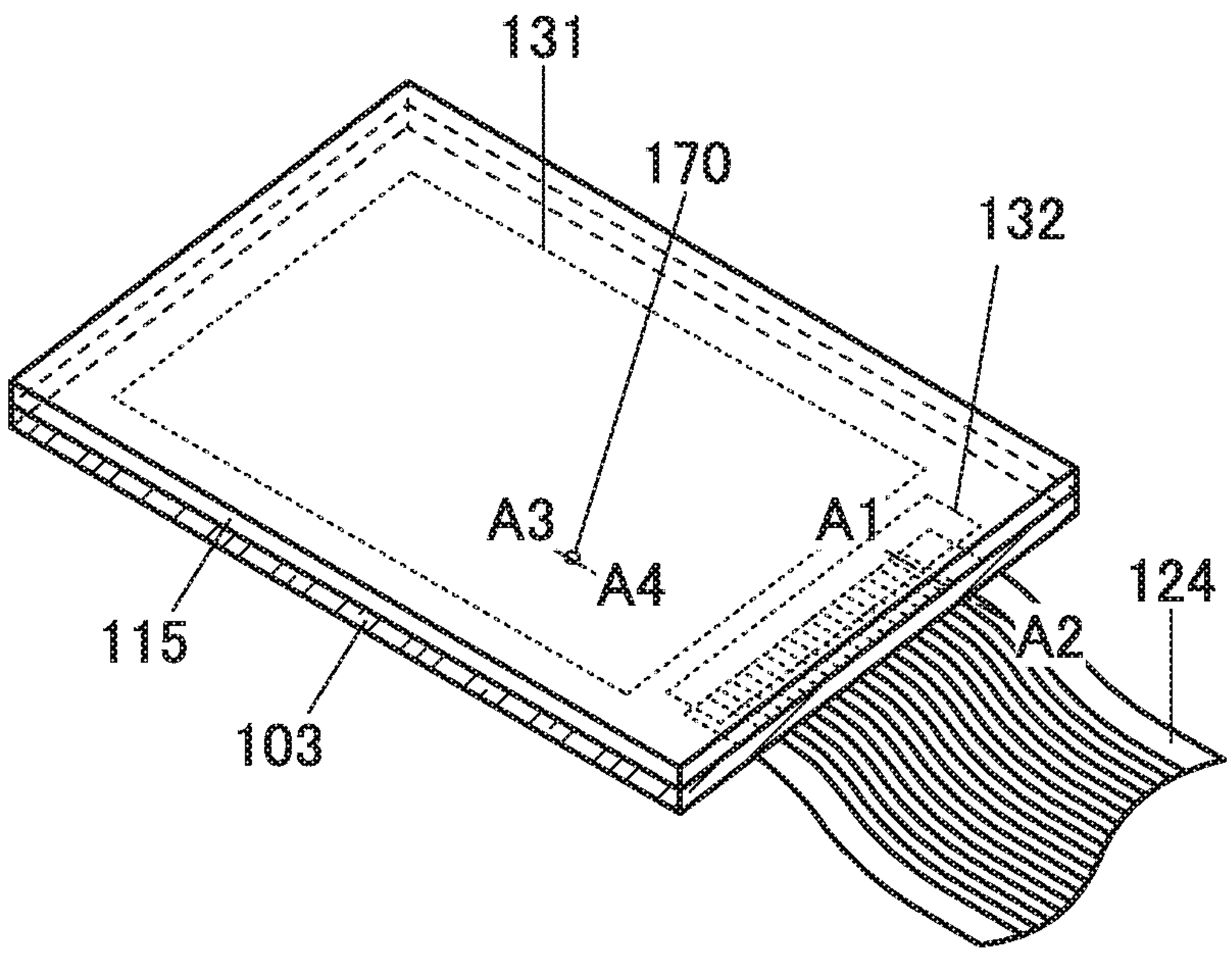


FIG. 3A

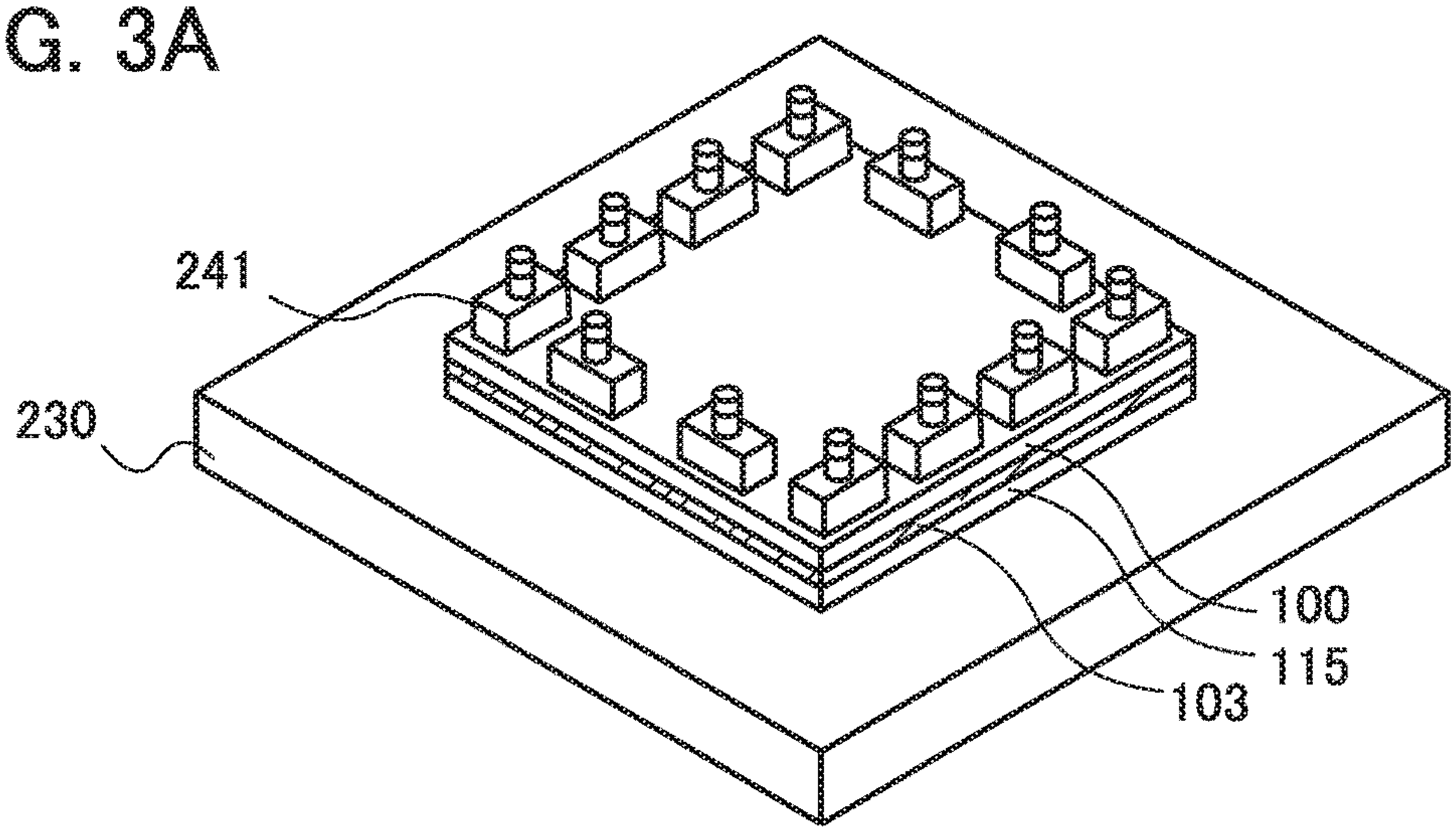


FIG. 3B

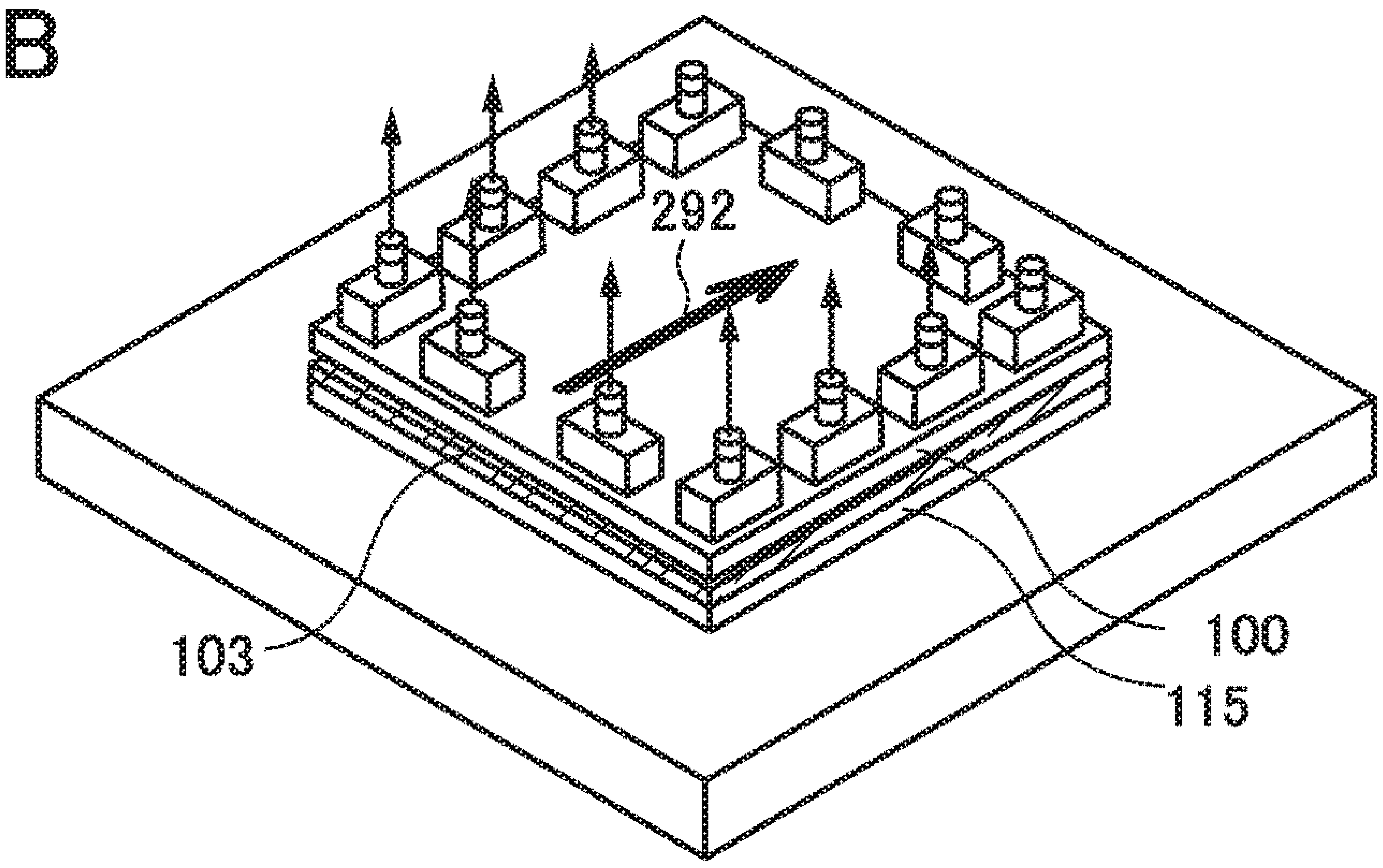


FIG. 3C

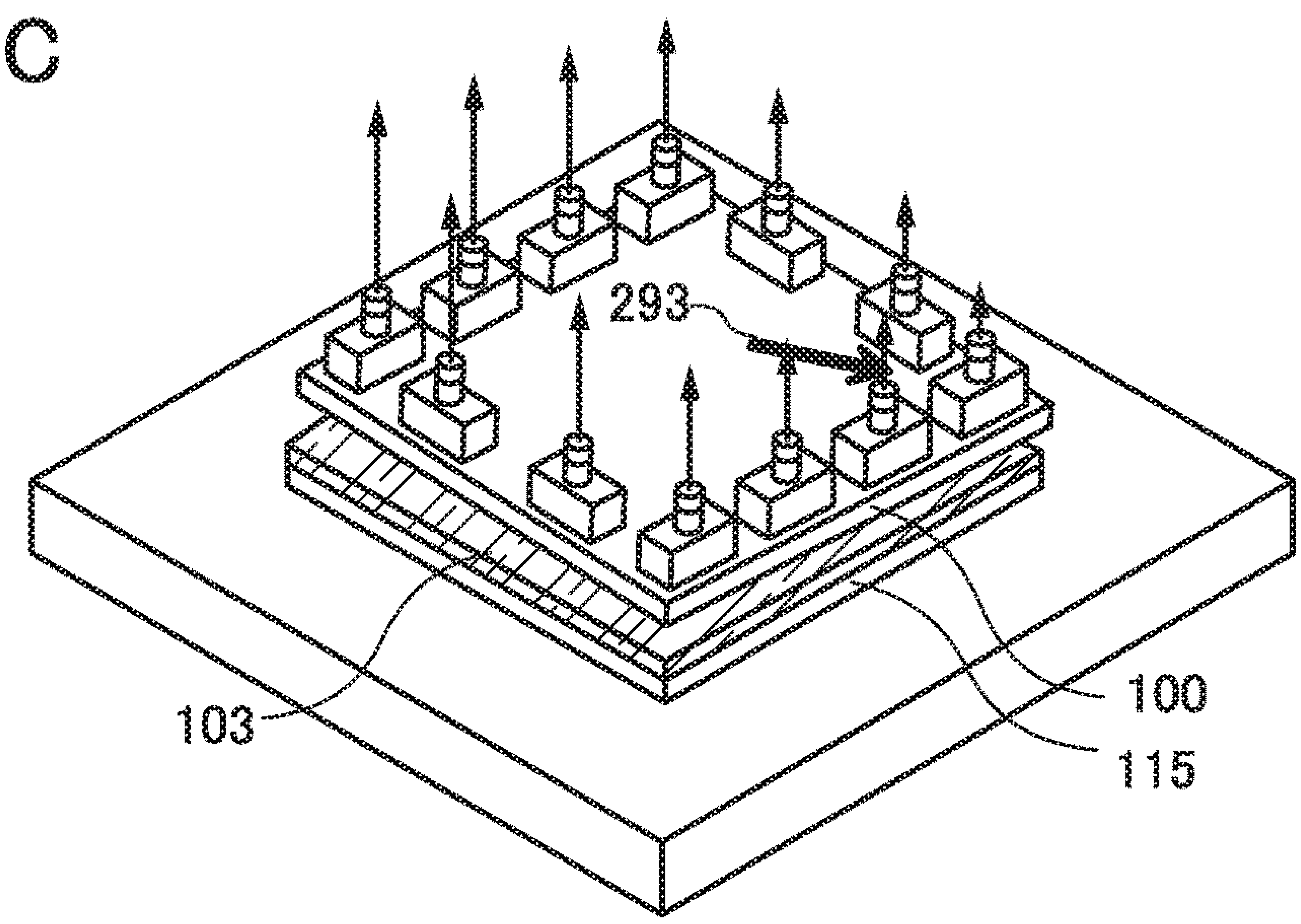


FIG. 4A

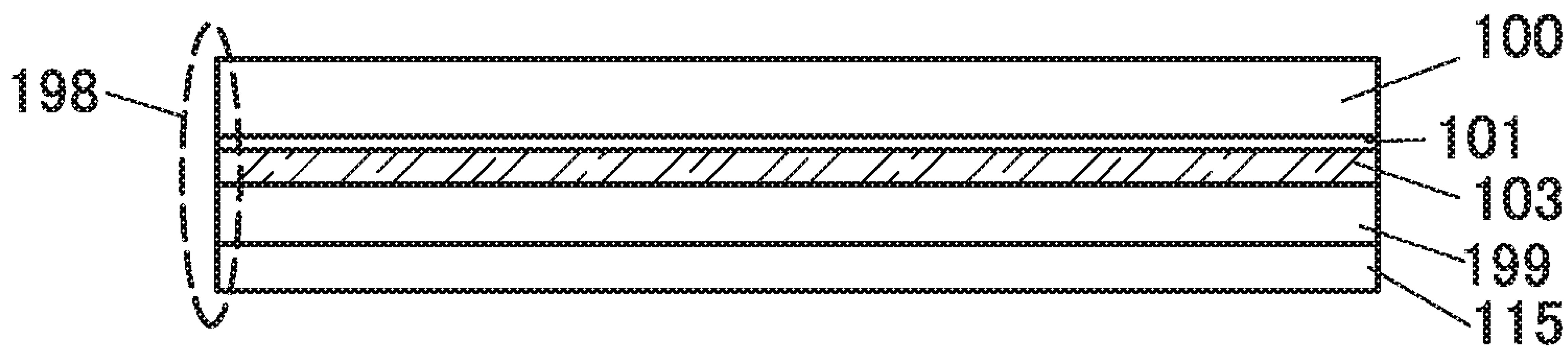


FIG. 4B

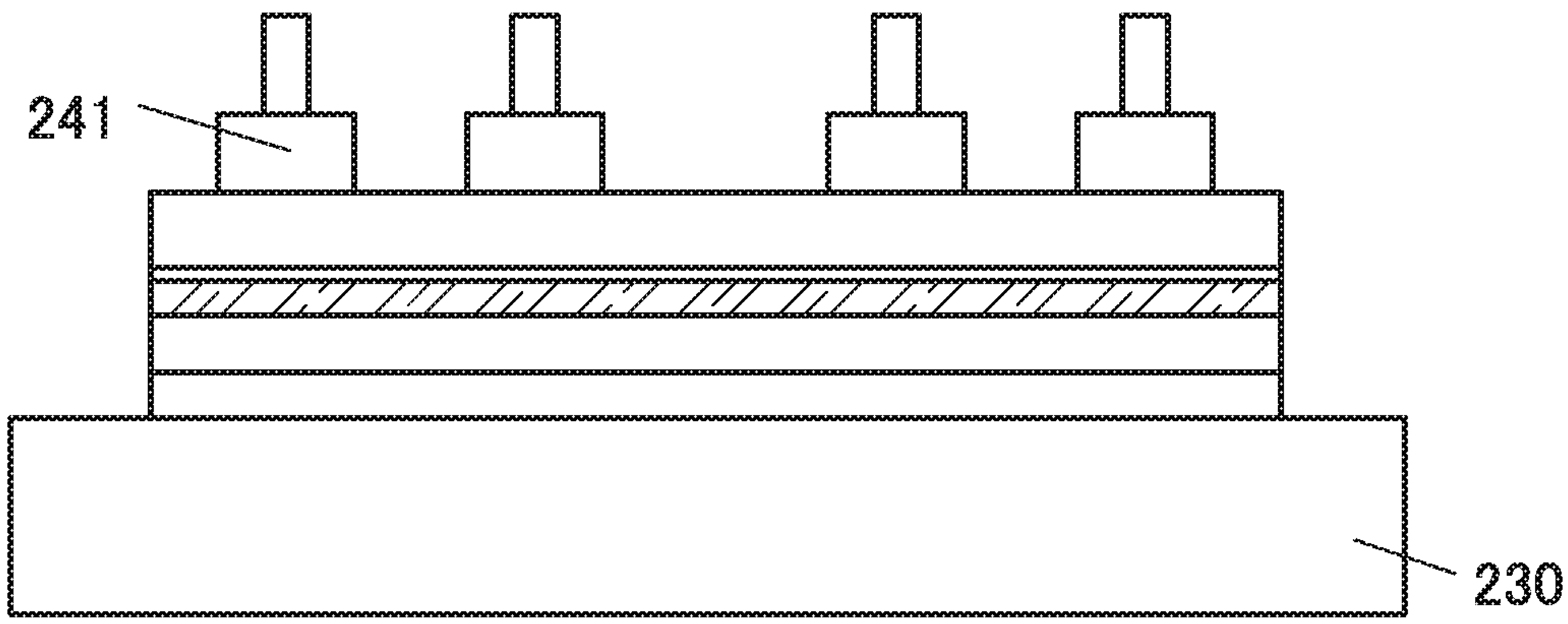


FIG. 4C

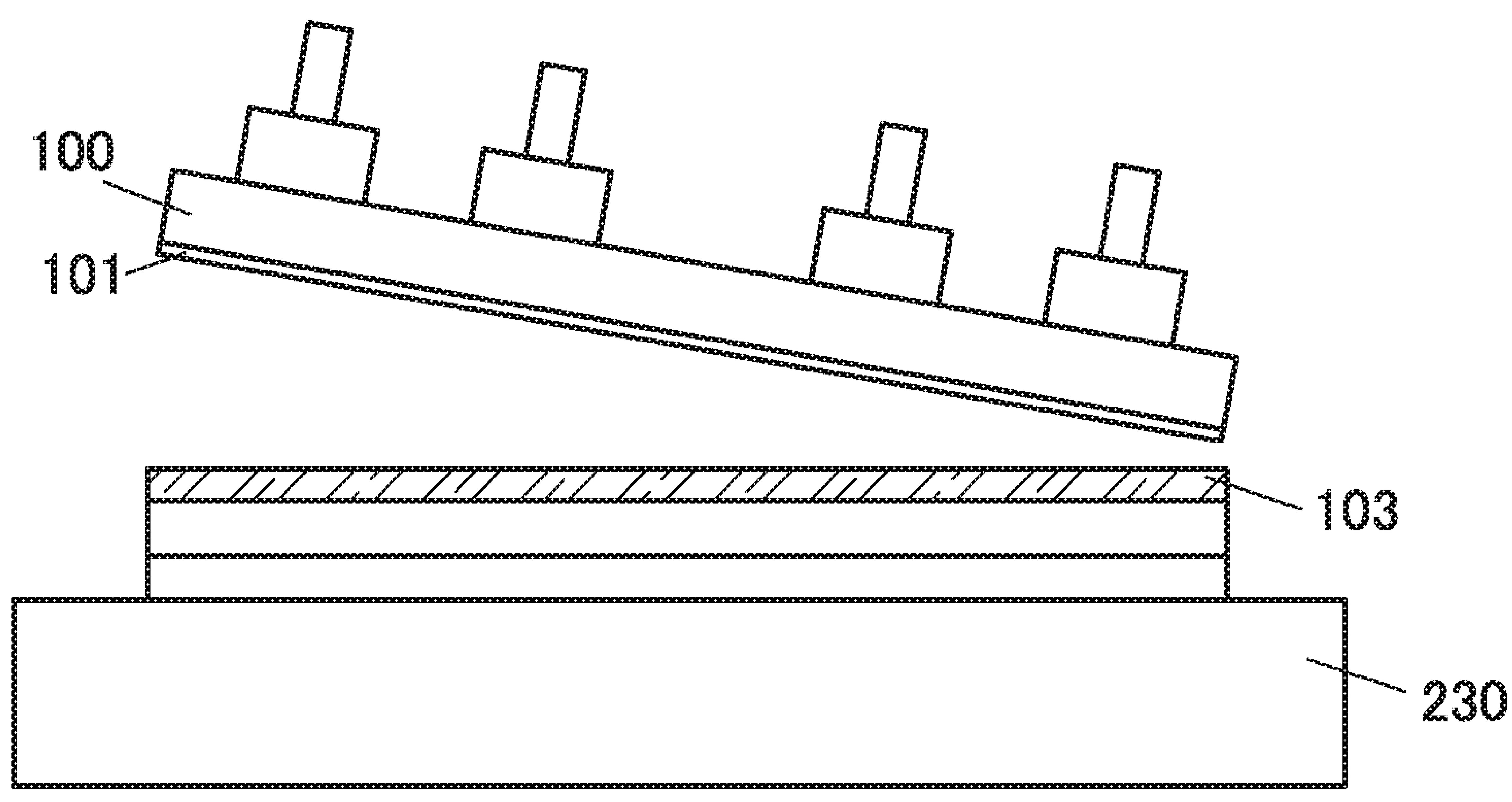


FIG. 5

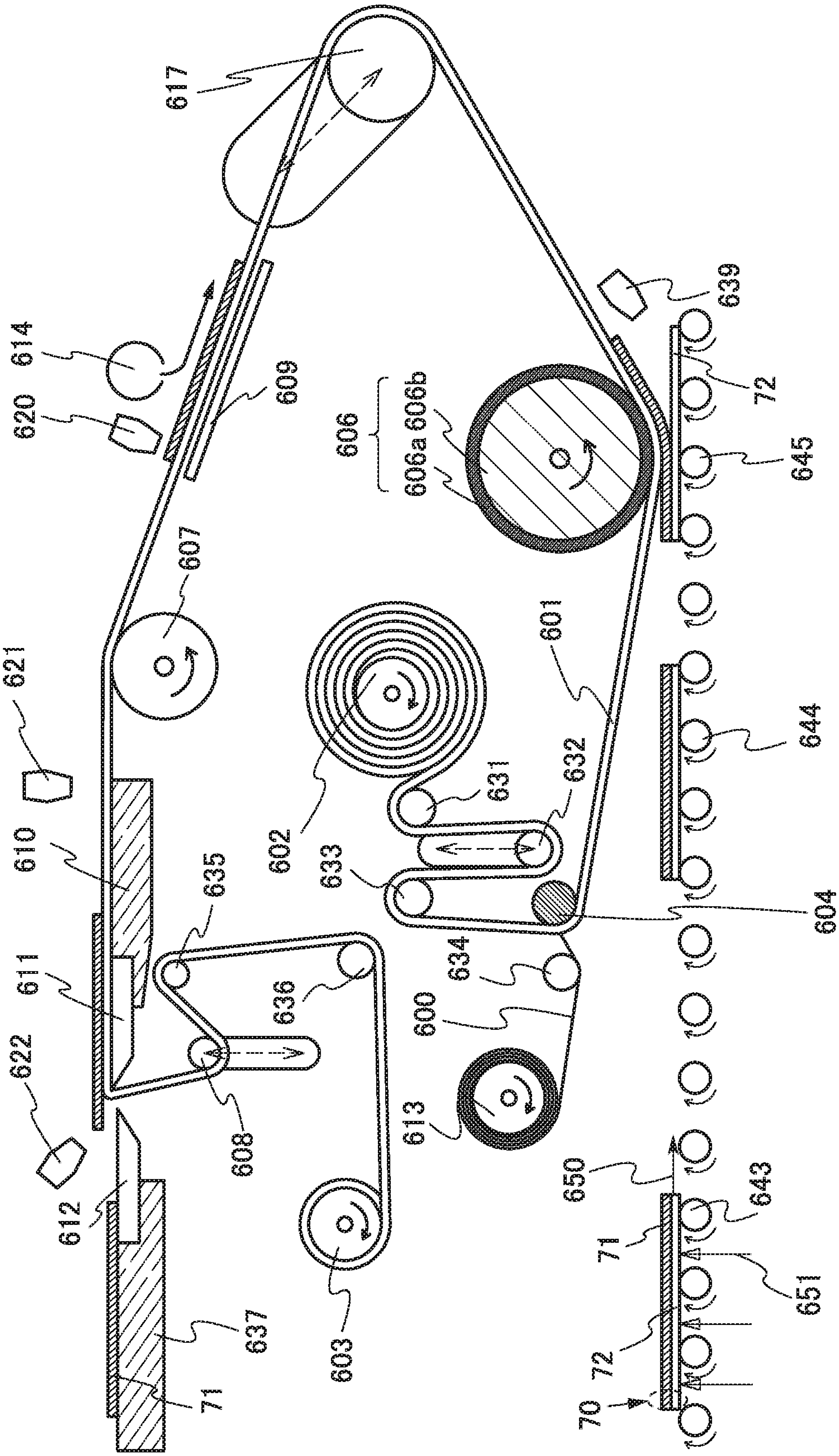

617
614
620
609
639
606
606a 606b
72
645
607
601
621
644
631
632
610
602
633
604
611
635
634
636
600
622
608
613
612
650
643
71
651
637
603
72
70
71

FIG. 6

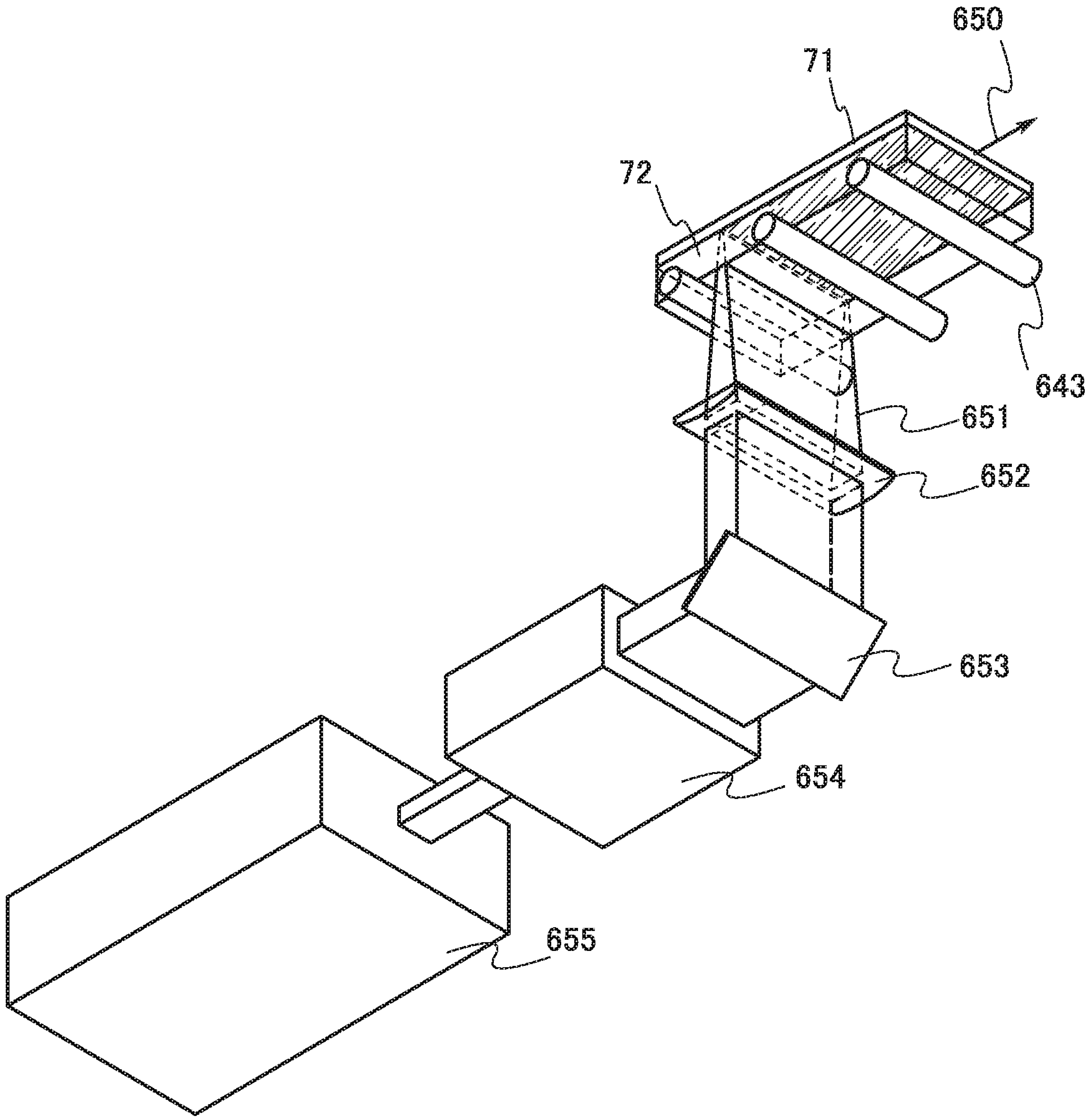


FIG. 7

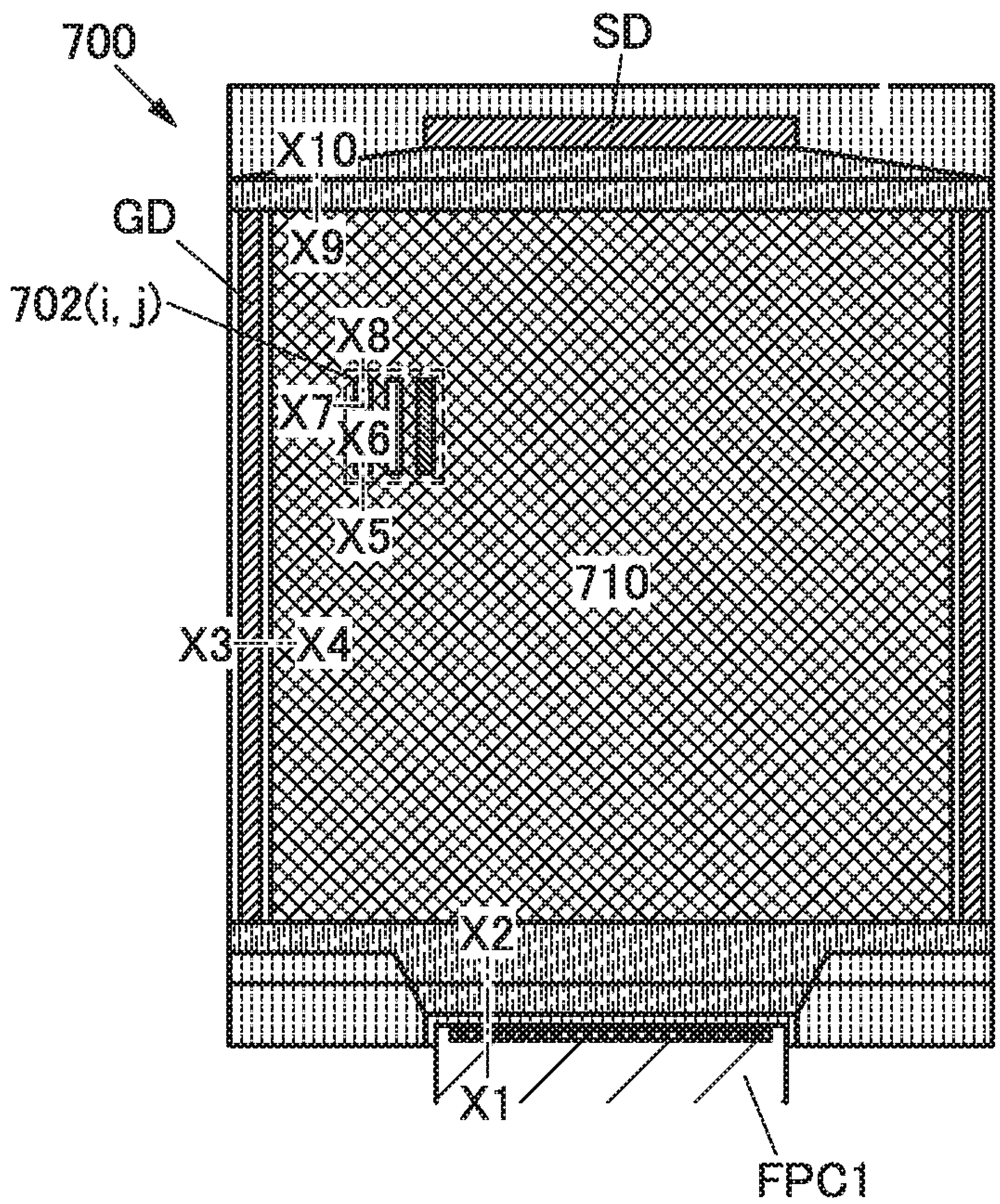
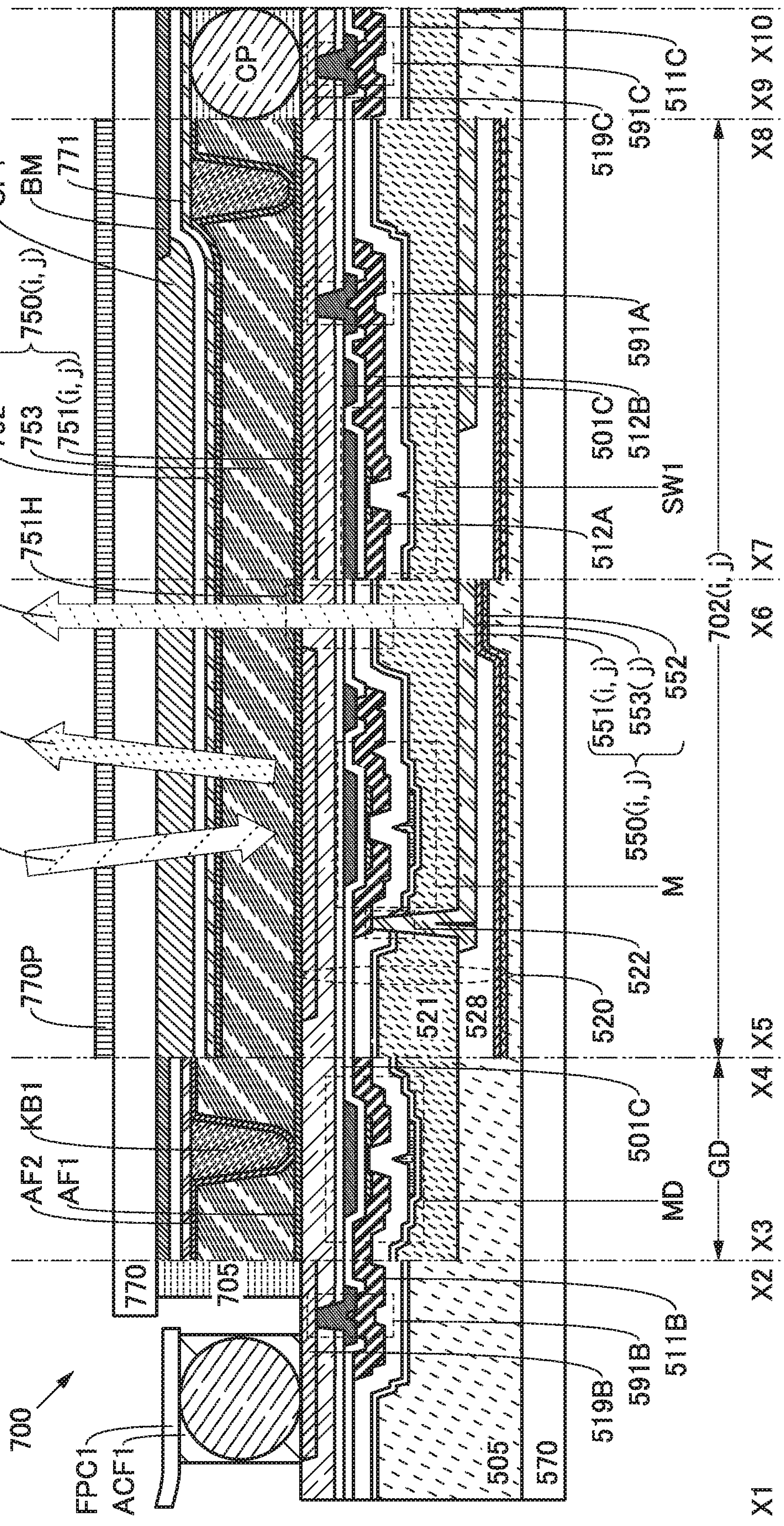


FIG. 8



700
FPC1
ACF1
AF2
AF1
KB1
770
705
770P
761
762
763
751H
752
753
751(i, j)
750(i, j)
CF1
BM
771
CP
505
570
519B
591B
511B
MD
501C
GD
521
528
520
522
M
550(i, j)
551(i, j)
553(j)
552
512A
SW1
501C
512B
591A
702(i, j)
519C
591C
511C
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10

FIG. 9

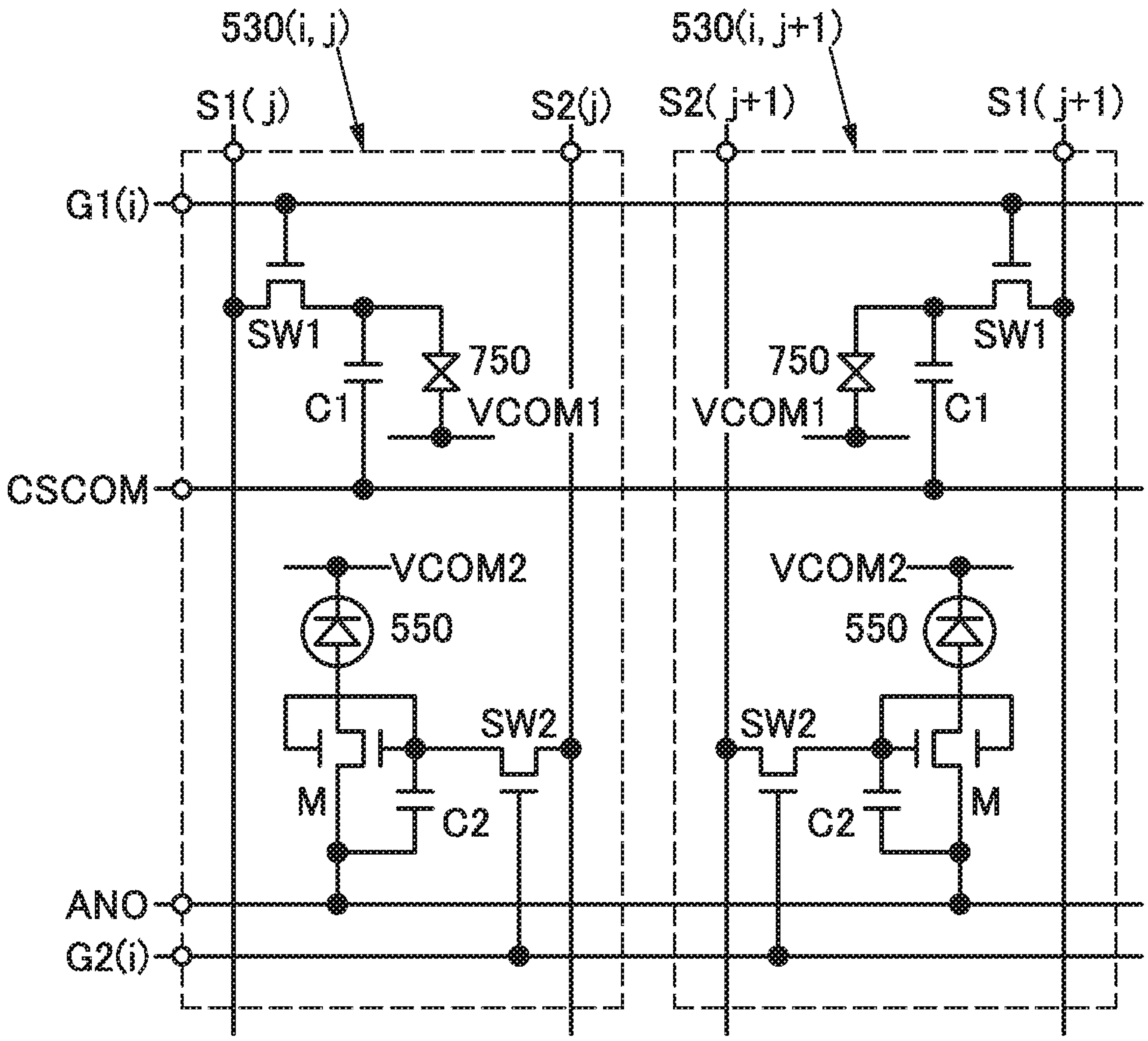

530(i, j)
530(i, j+1)
S1(j)
S2(j)
S2(j+1)
S1(j+1)
G1(i)
SW1
750
C1
VCOM1
CSCOM
VCOM2
550
SW2
M
C2
ANO
G2(i)

FIG. 10A

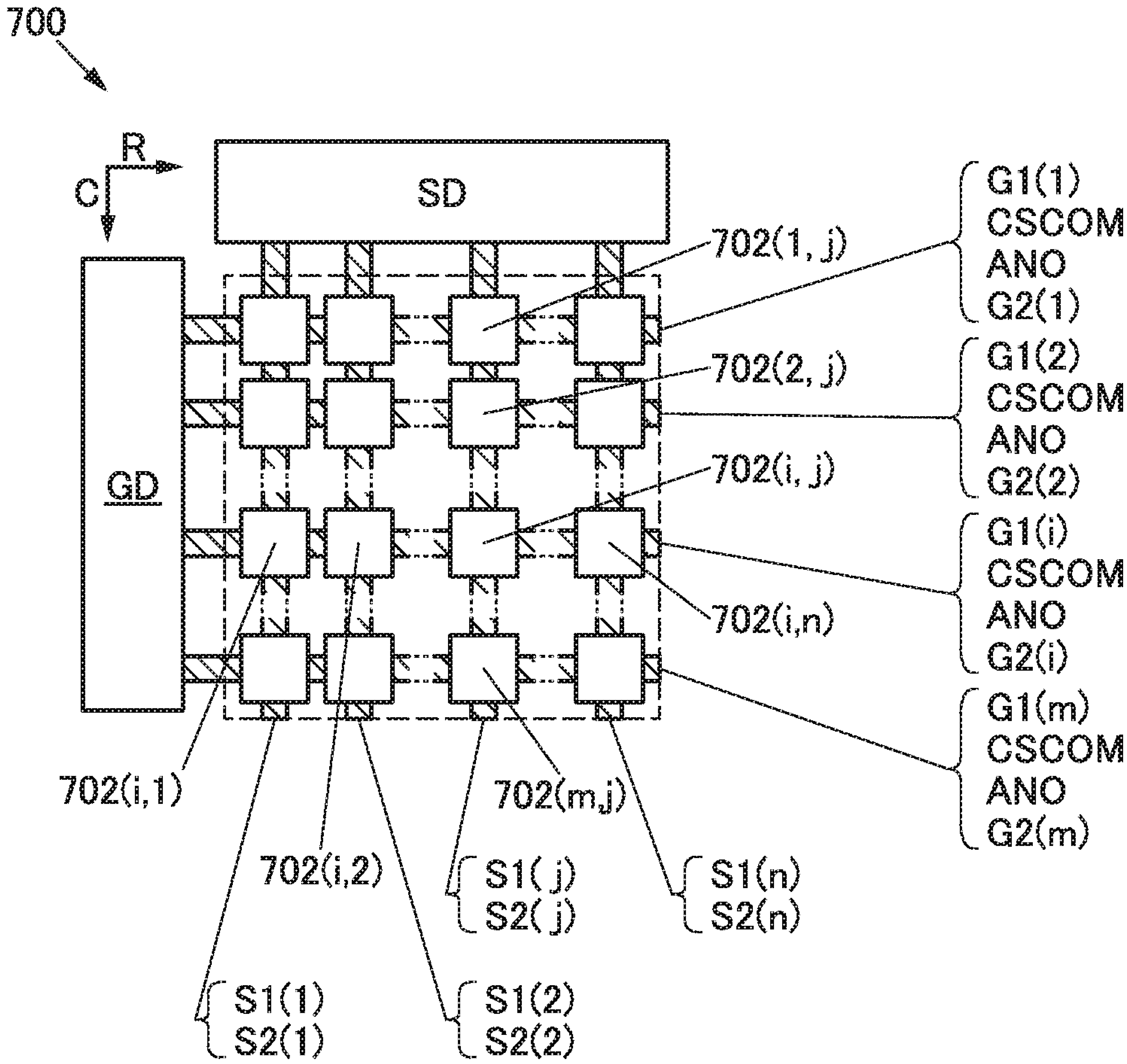


FIG. 10B1

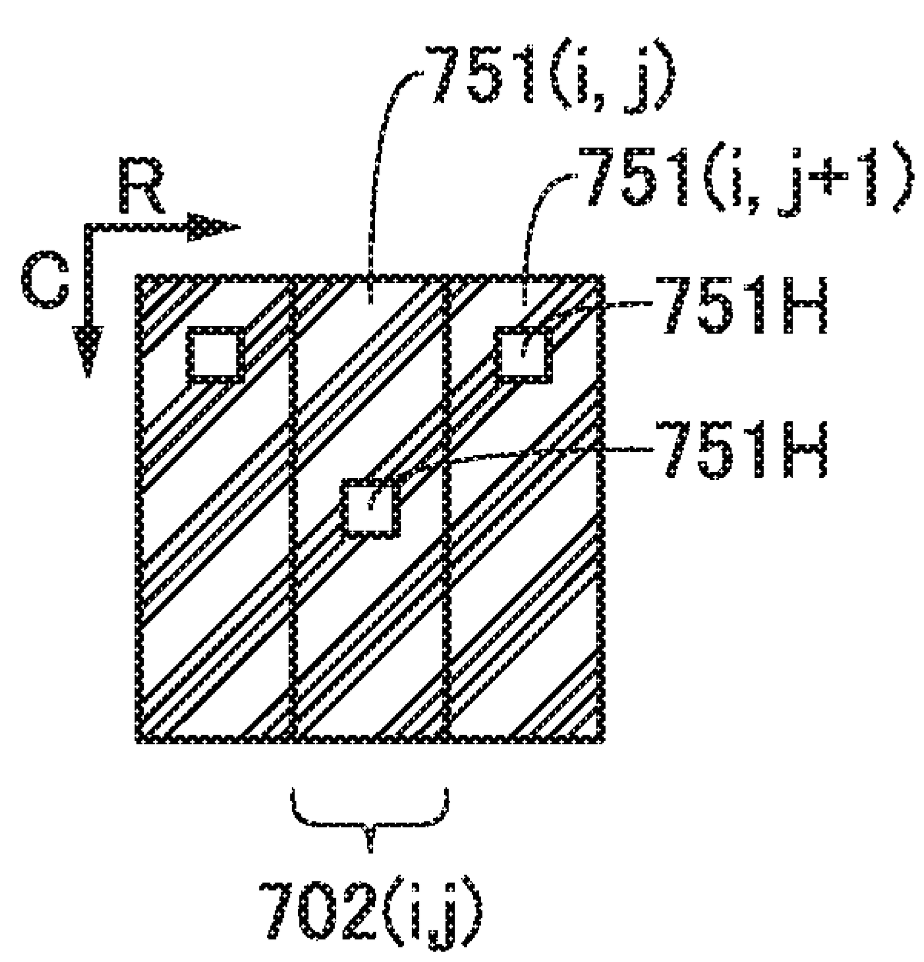


FIG. 10B2

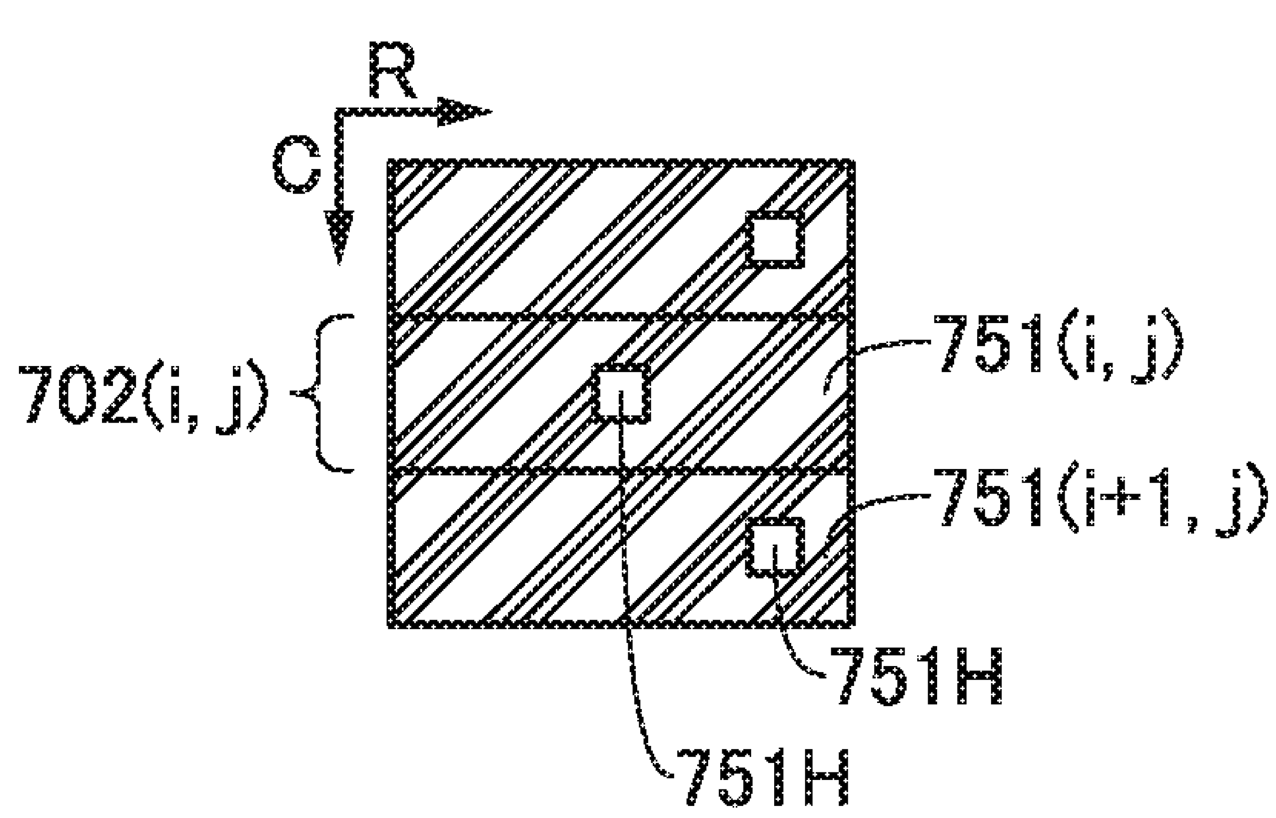
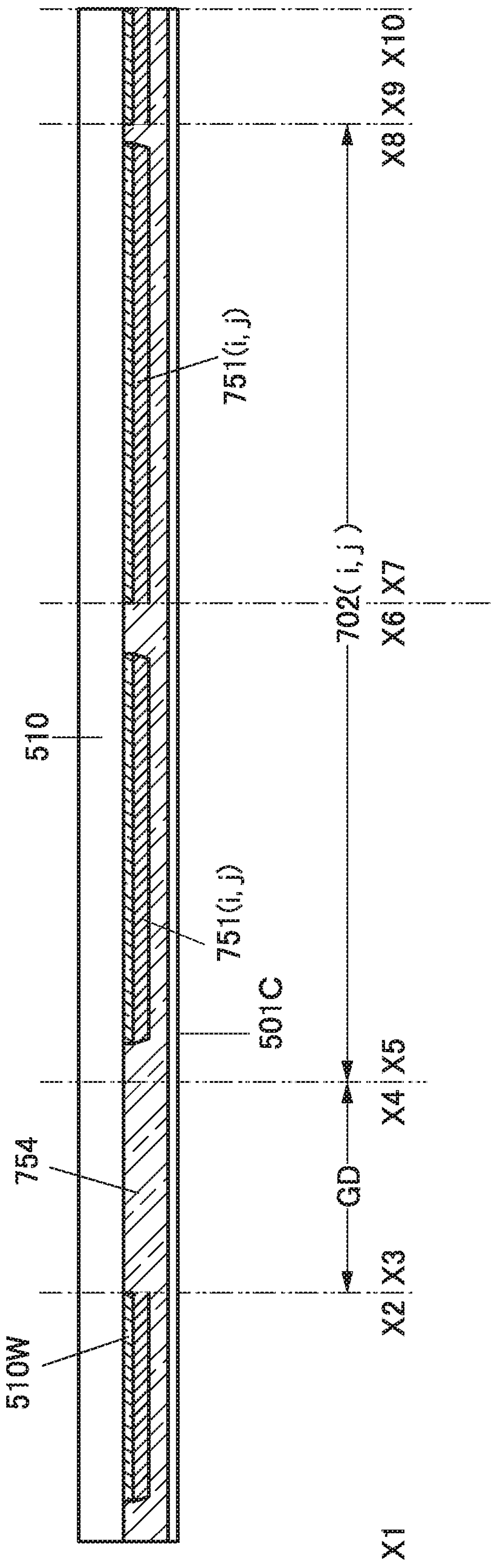


FIG. 11



510
510W
754
751(i, j)
751(i, j)
501C
702(i, j)
GD
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10

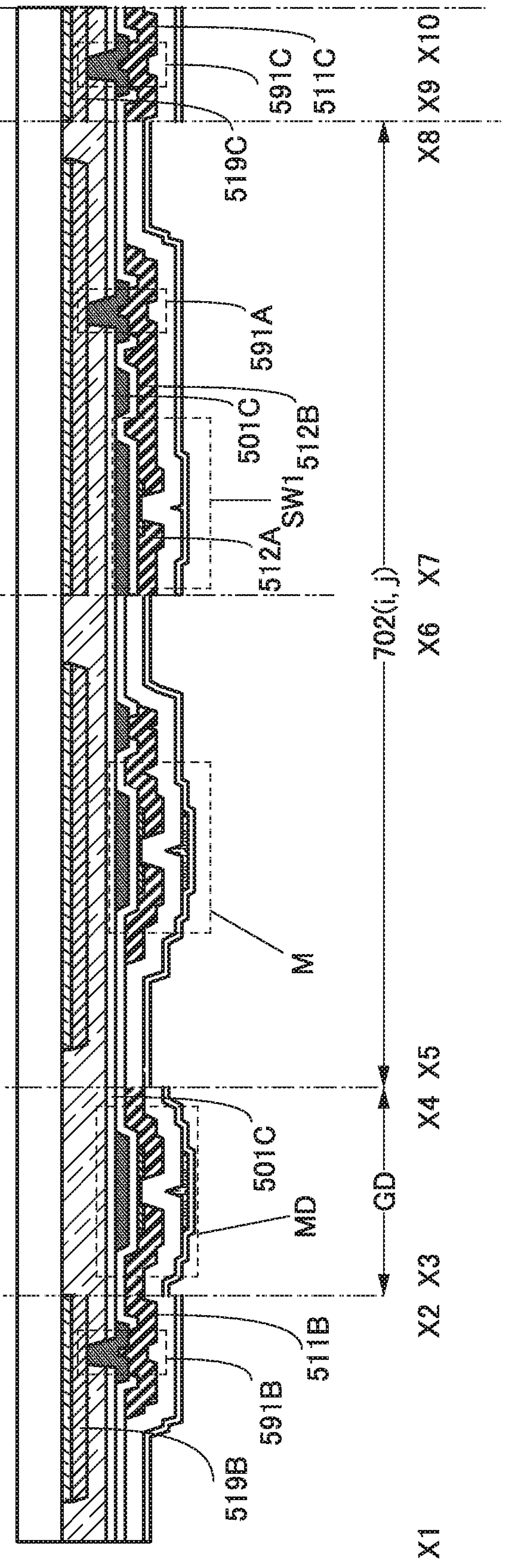


FIG. 12A

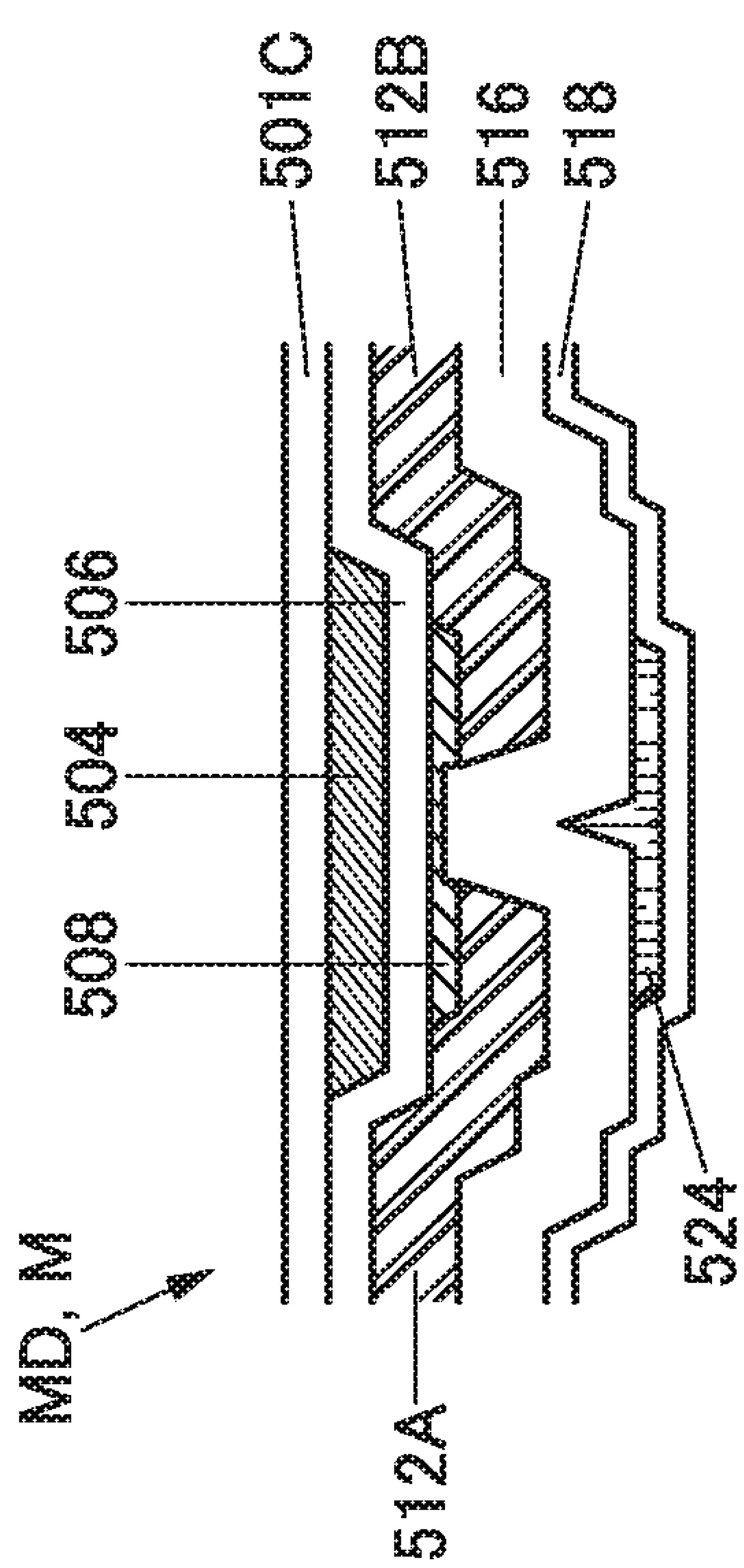


FIG. 12B

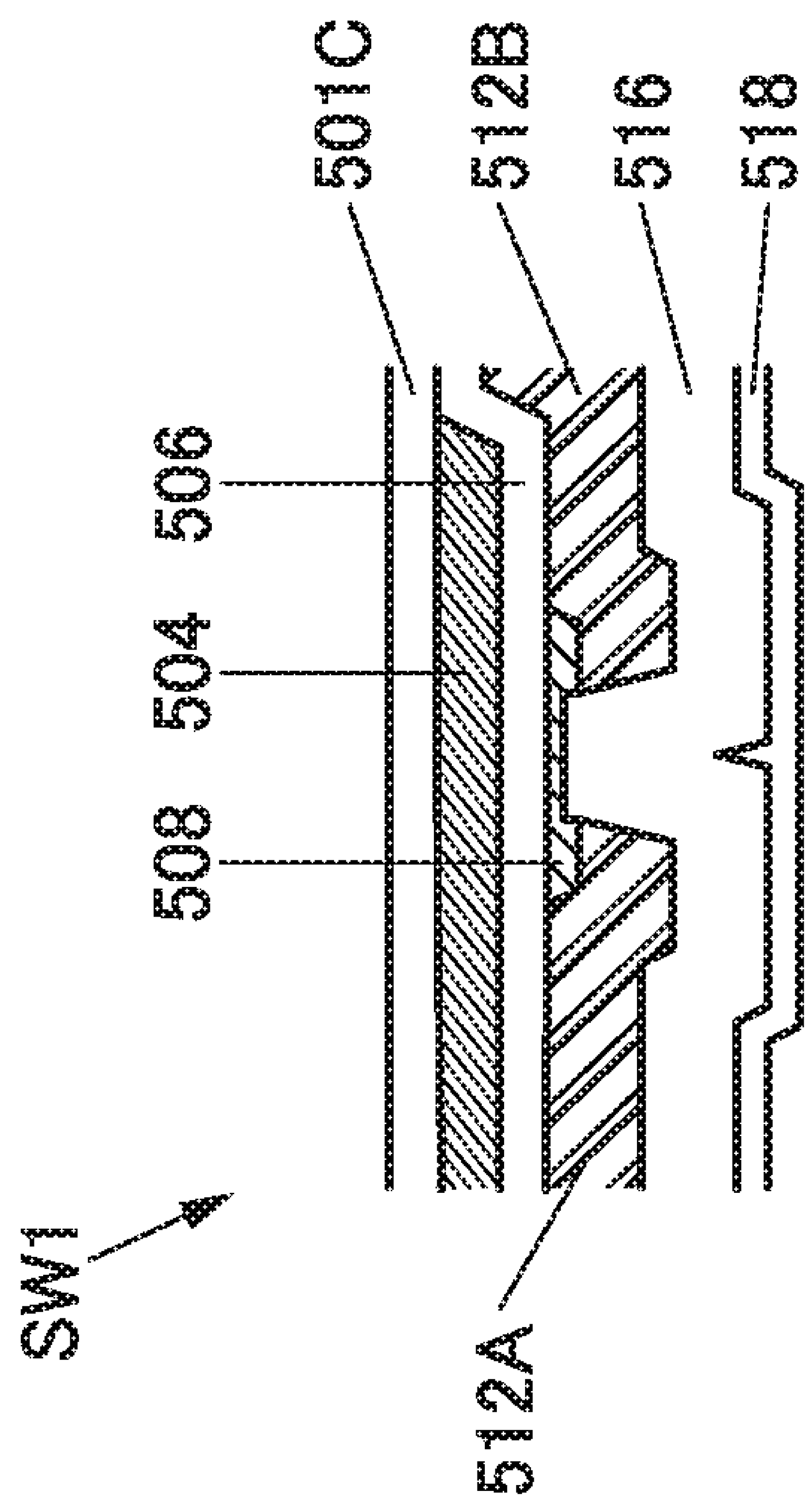
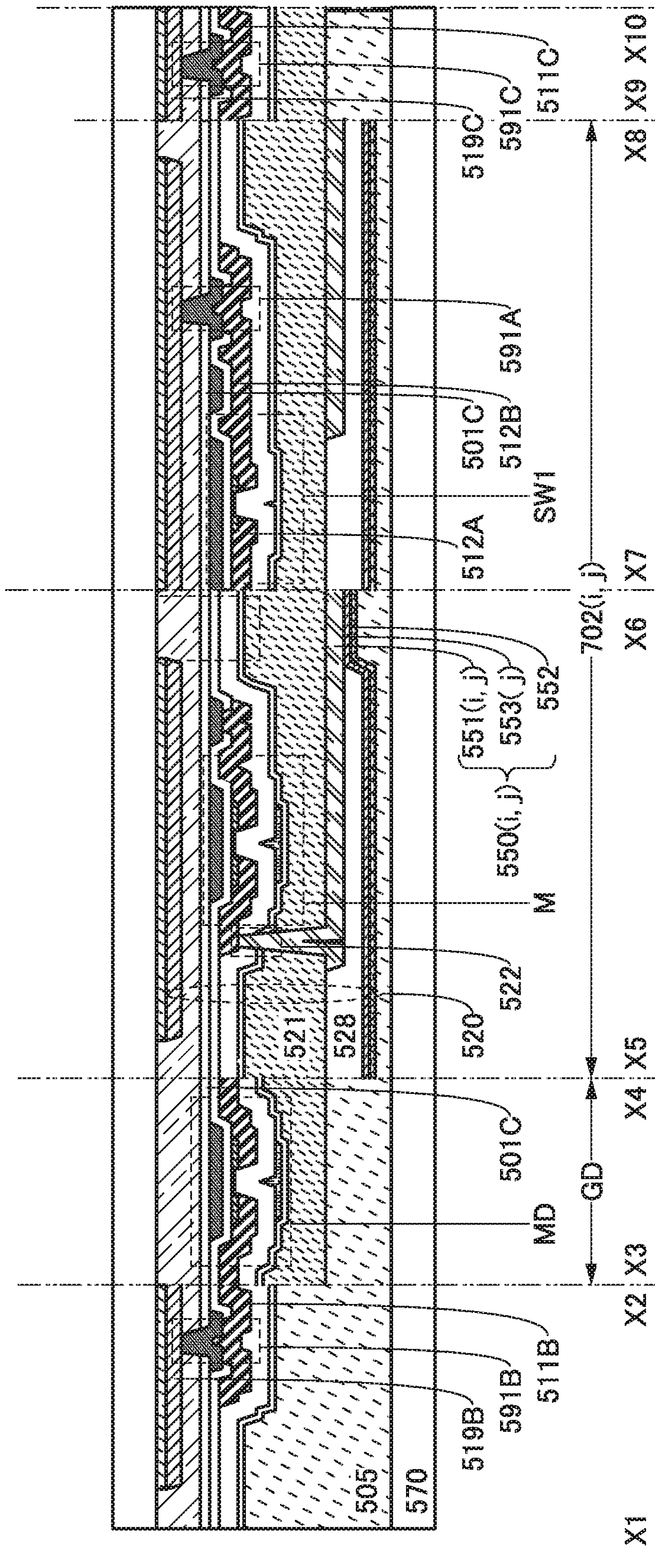


FIG. 12C

FIG. 13



X1
X2
X3
X4
X5
X6
X7
X8
X9
X10
505
570
519B
591B
511B
MD
GD
501C
521
528
520
522
M
550(i, j)
551(i, j)
553(j)
552
702(i, j)
512A
SW1
501C
512B
591A
519C
591C
511C

FIG. 14

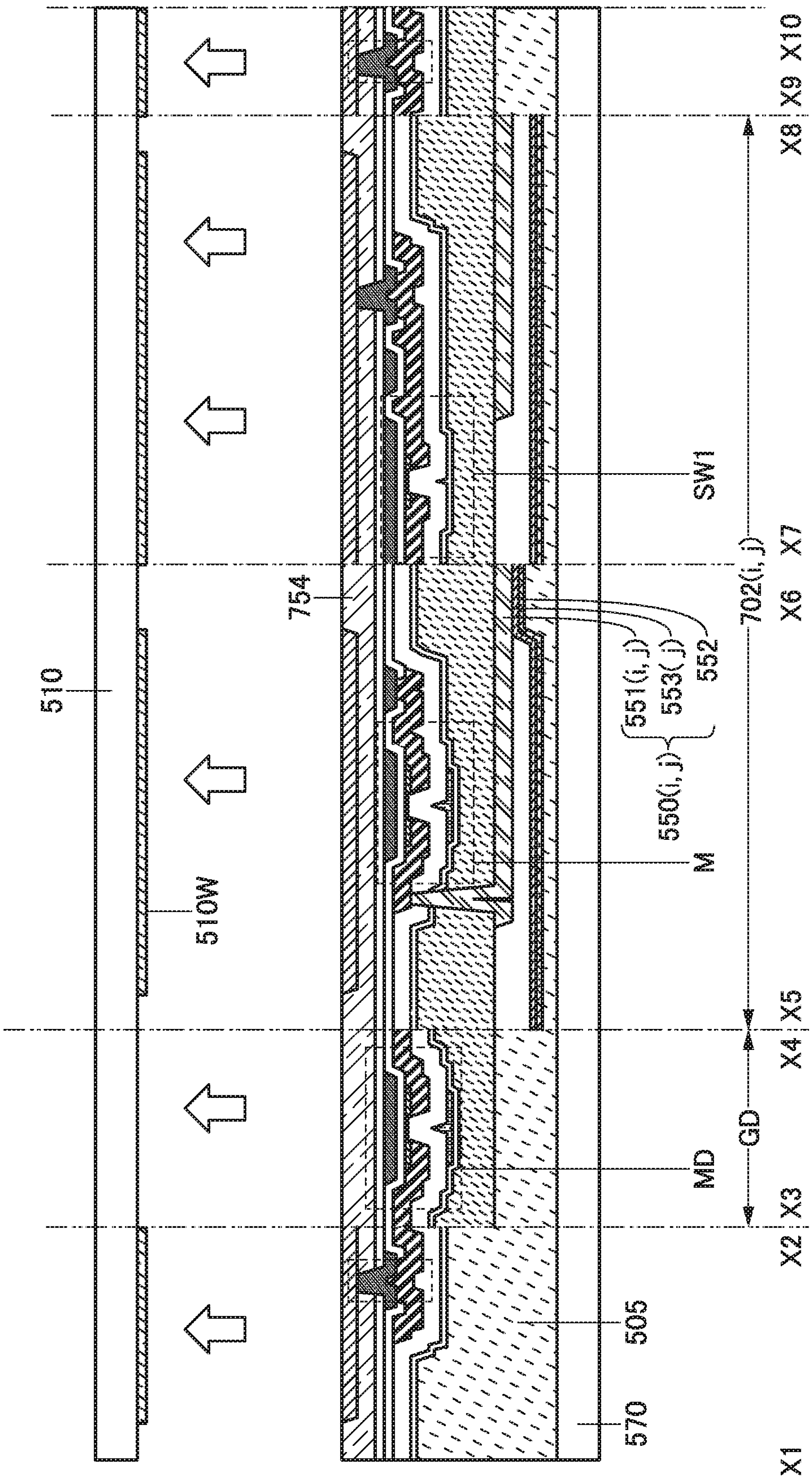

510
510W
754
505
570
MD
GD
M
SW1
550(i, j)
551(i, j)
553(i, j)
552
702(i, j)
X1
X2
X3
X4
X5
X6
X7
X8
X9
X10

FIG. 15

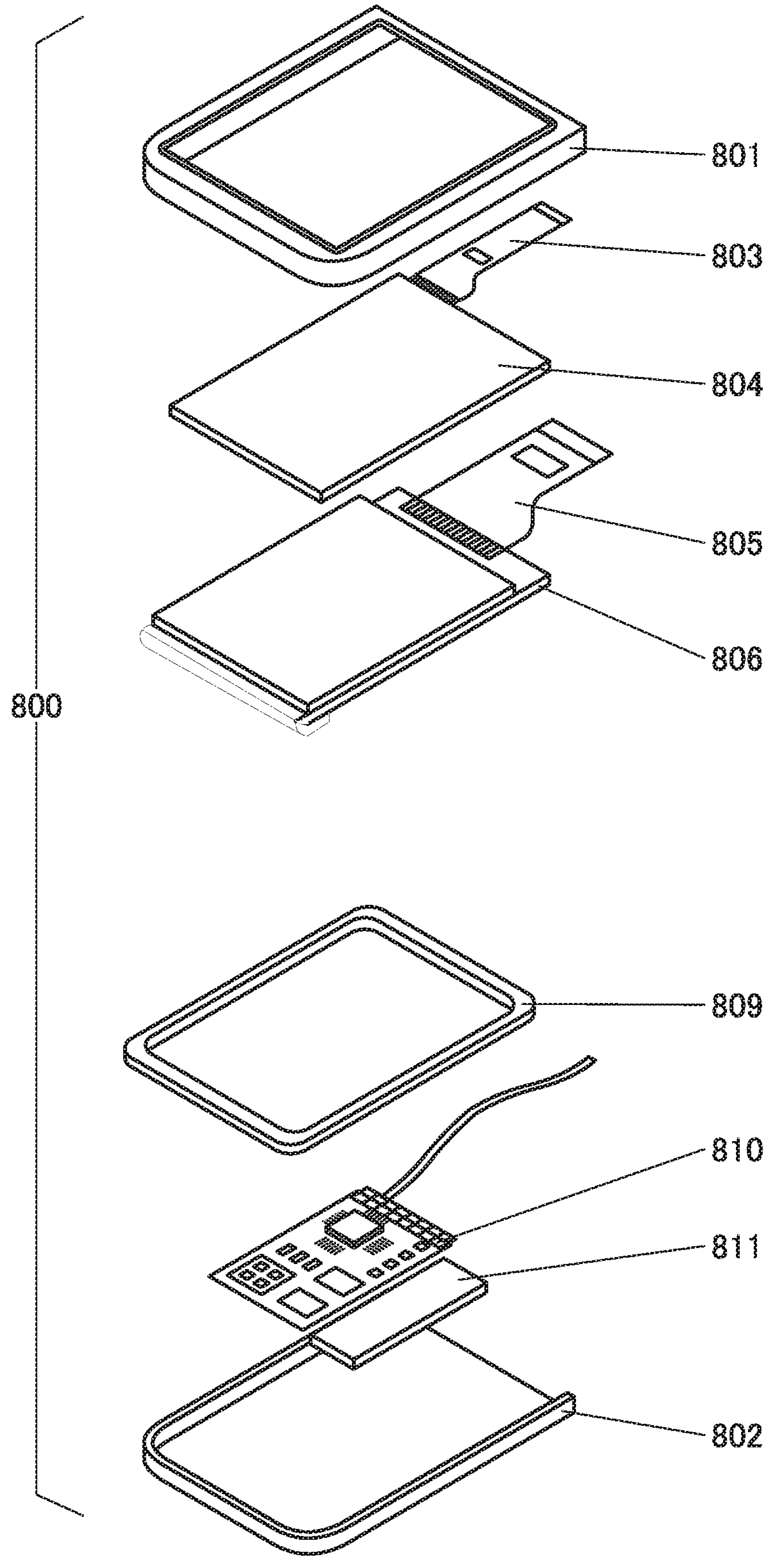


FIG. 16A

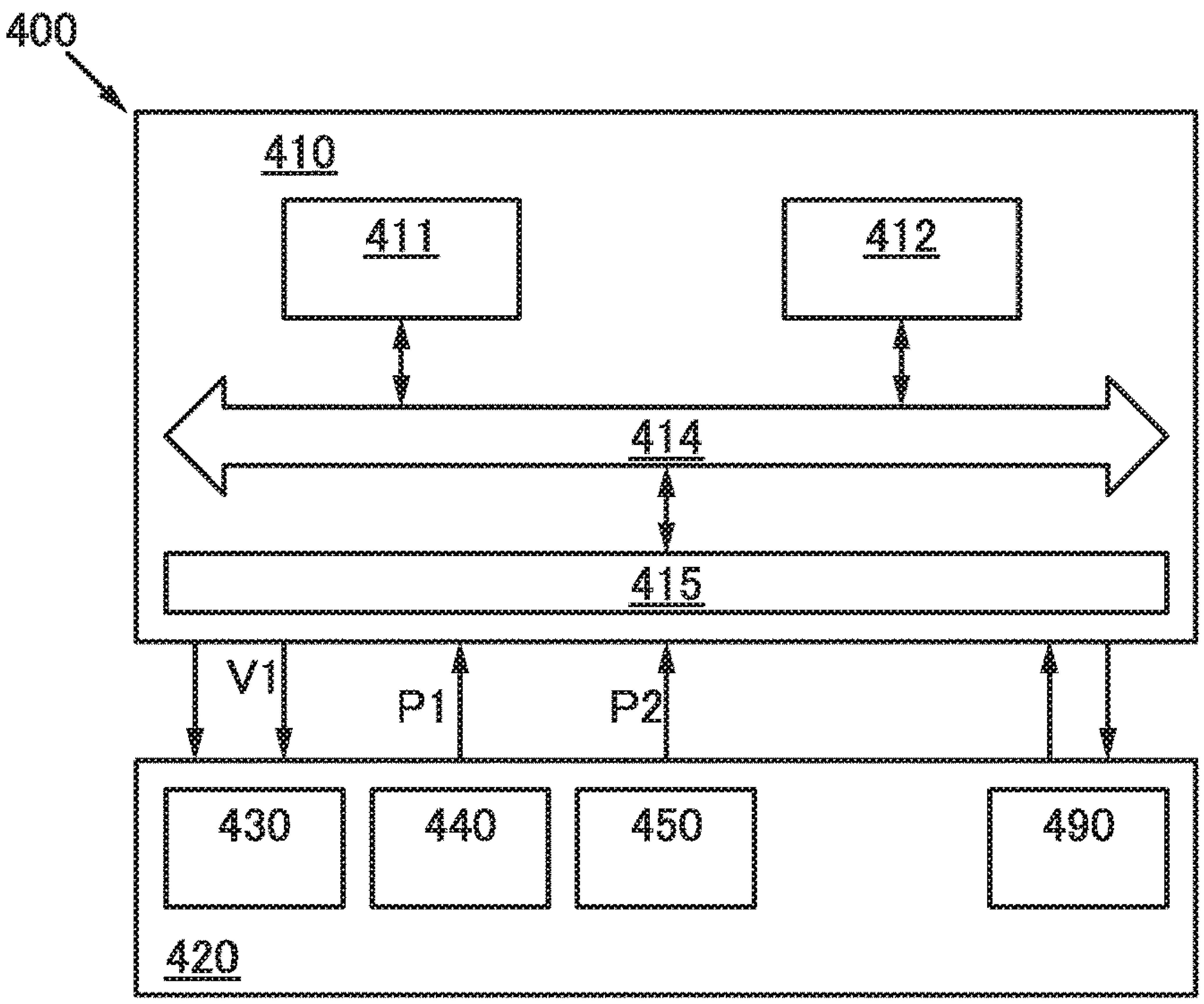


FIG. 16B

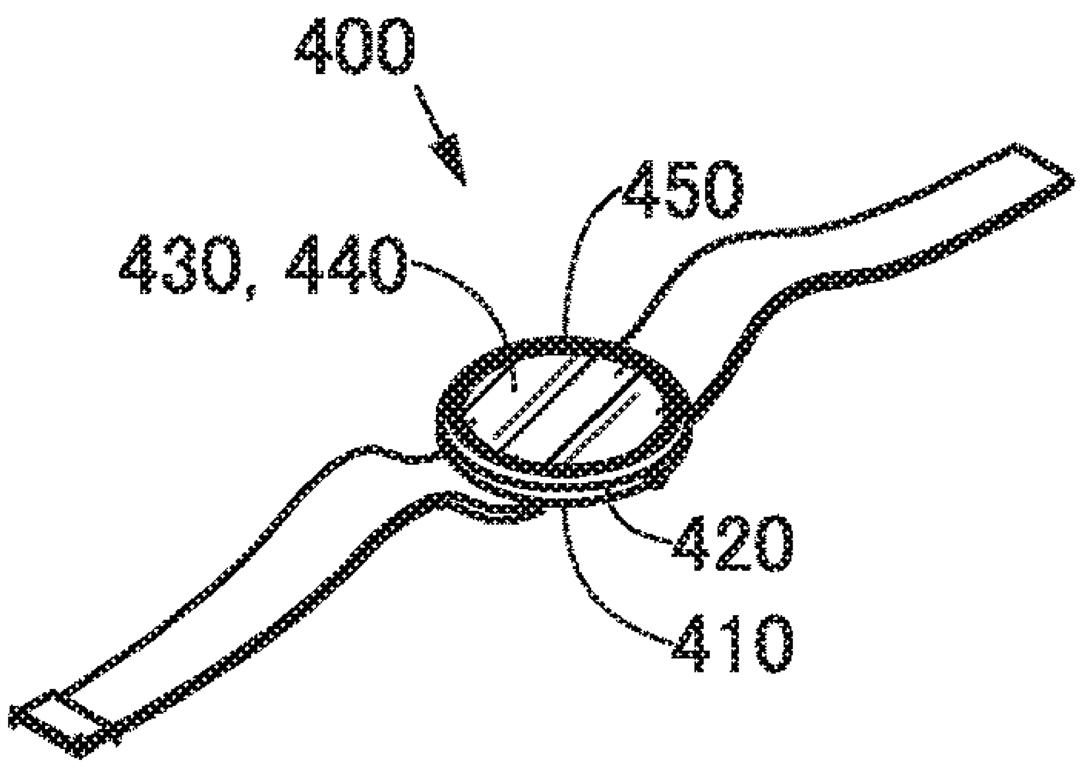


FIG. 16C

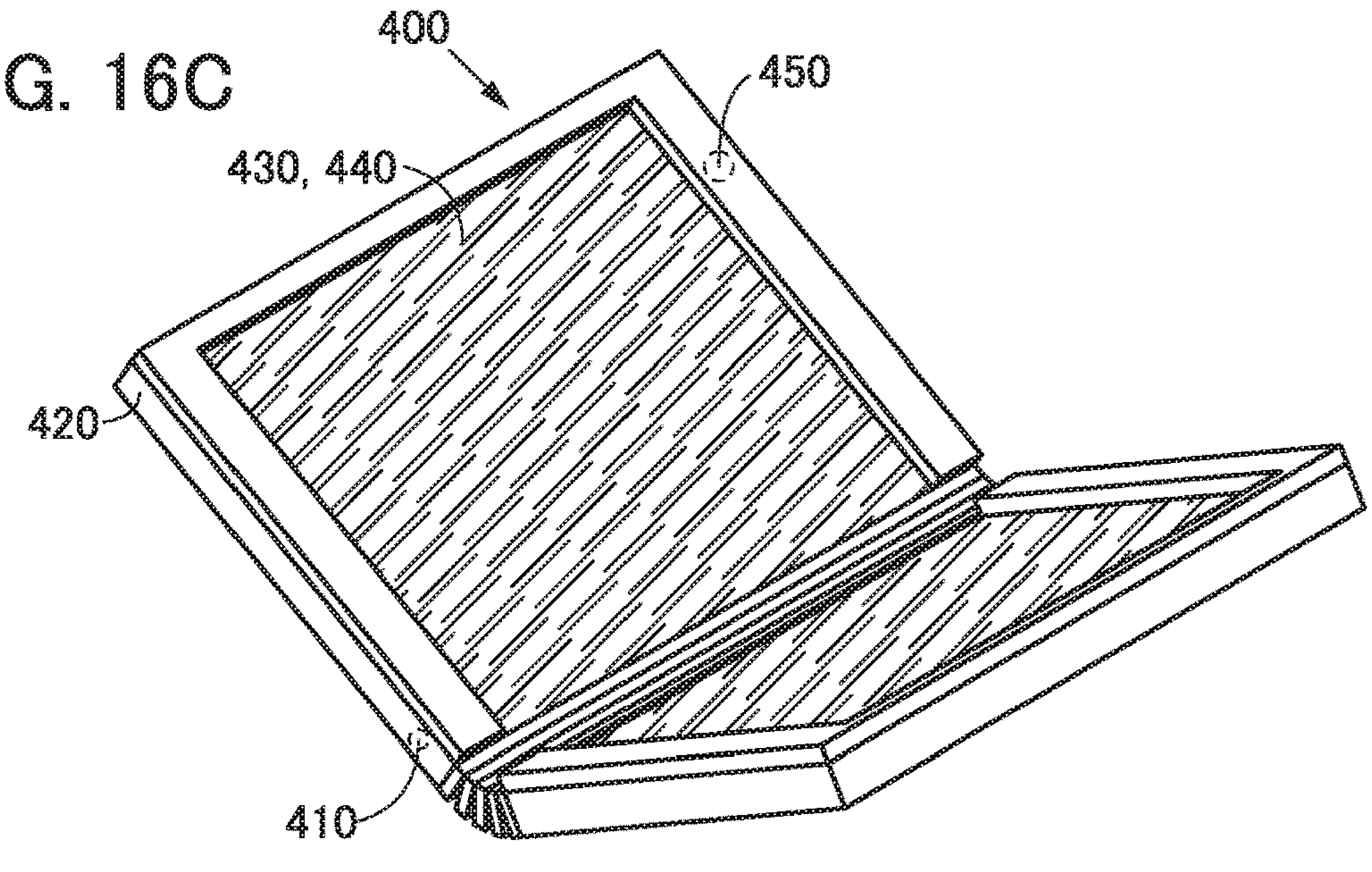


FIG. 17A

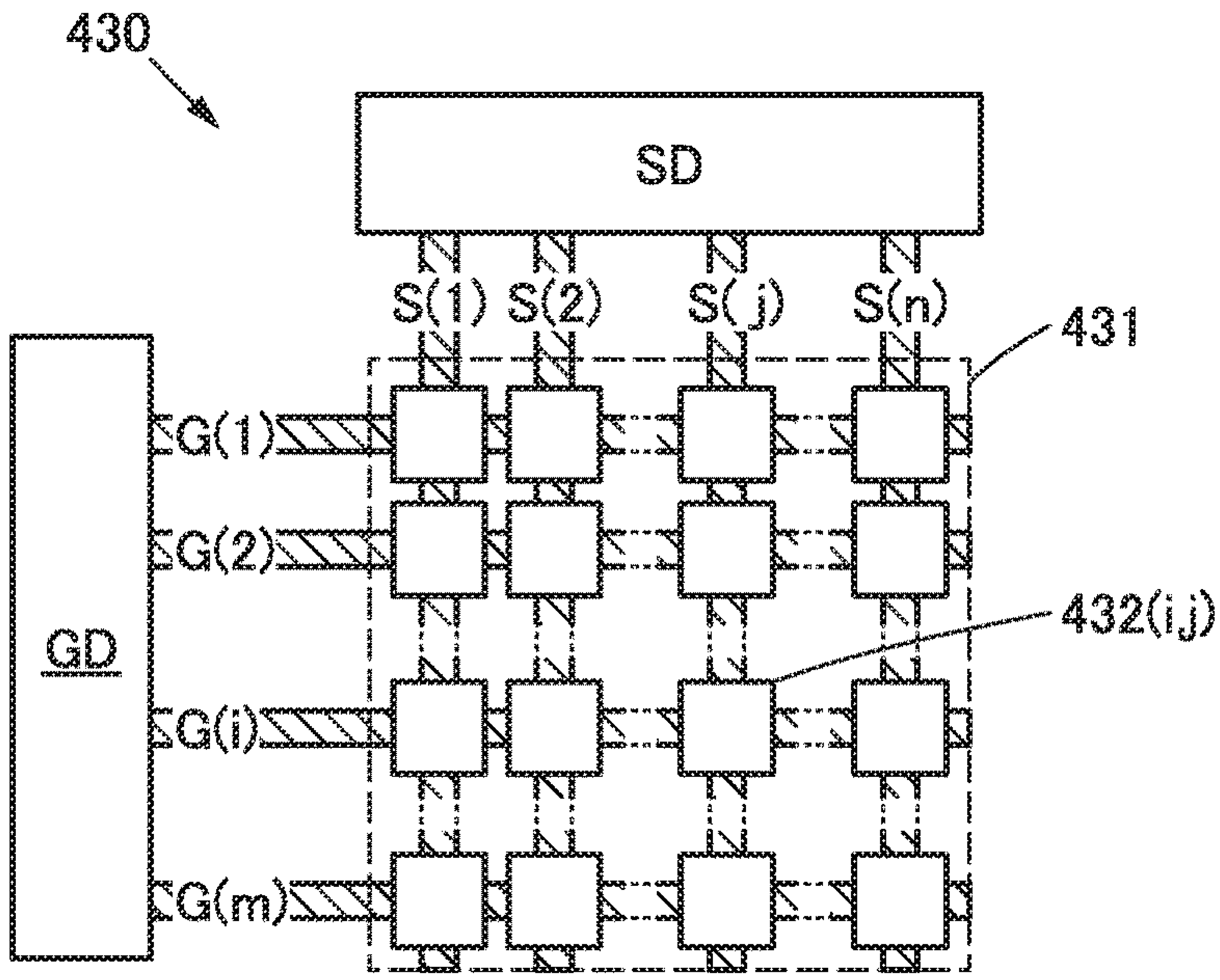


FIG. 17B

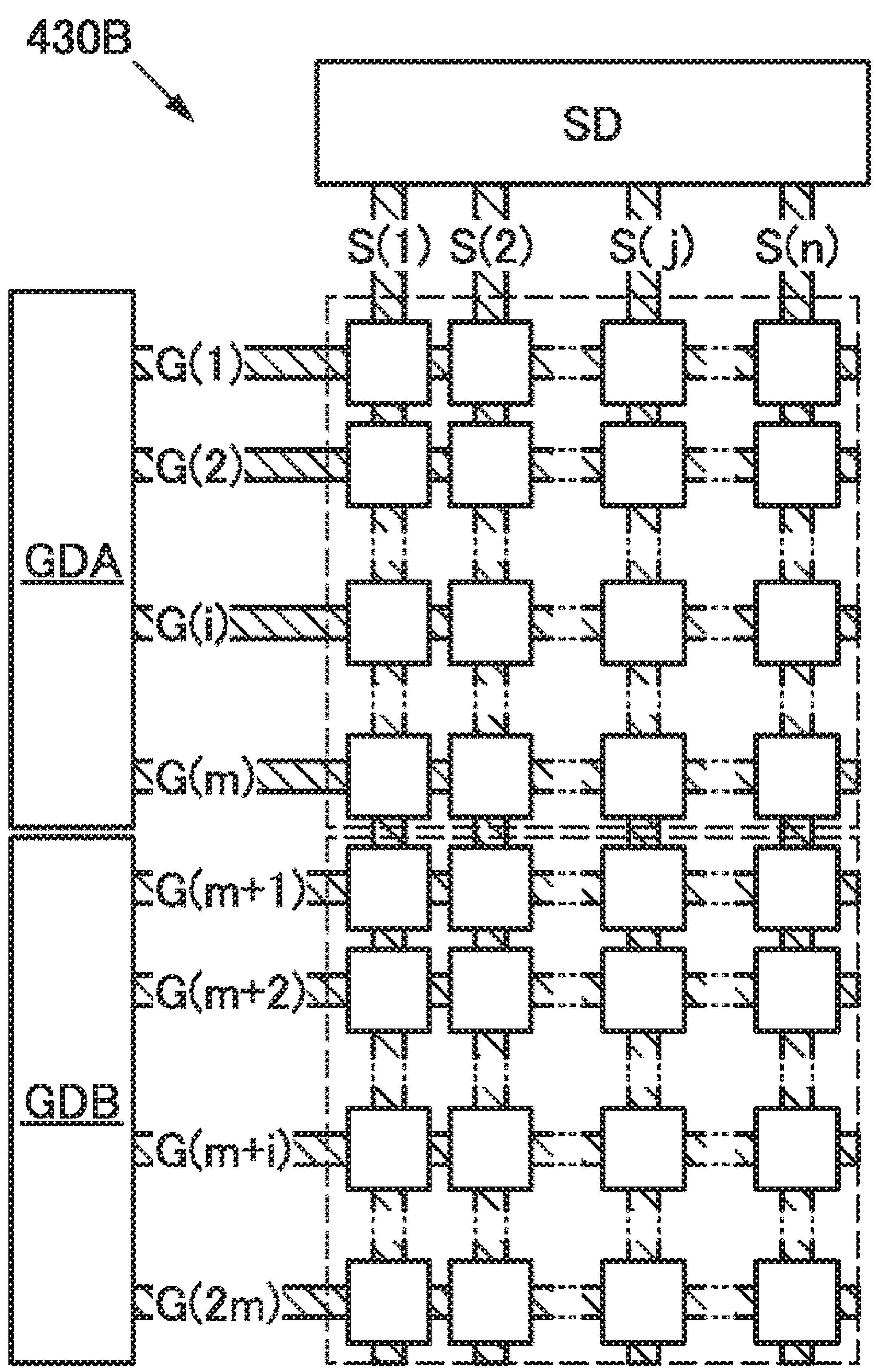


FIG. 17C

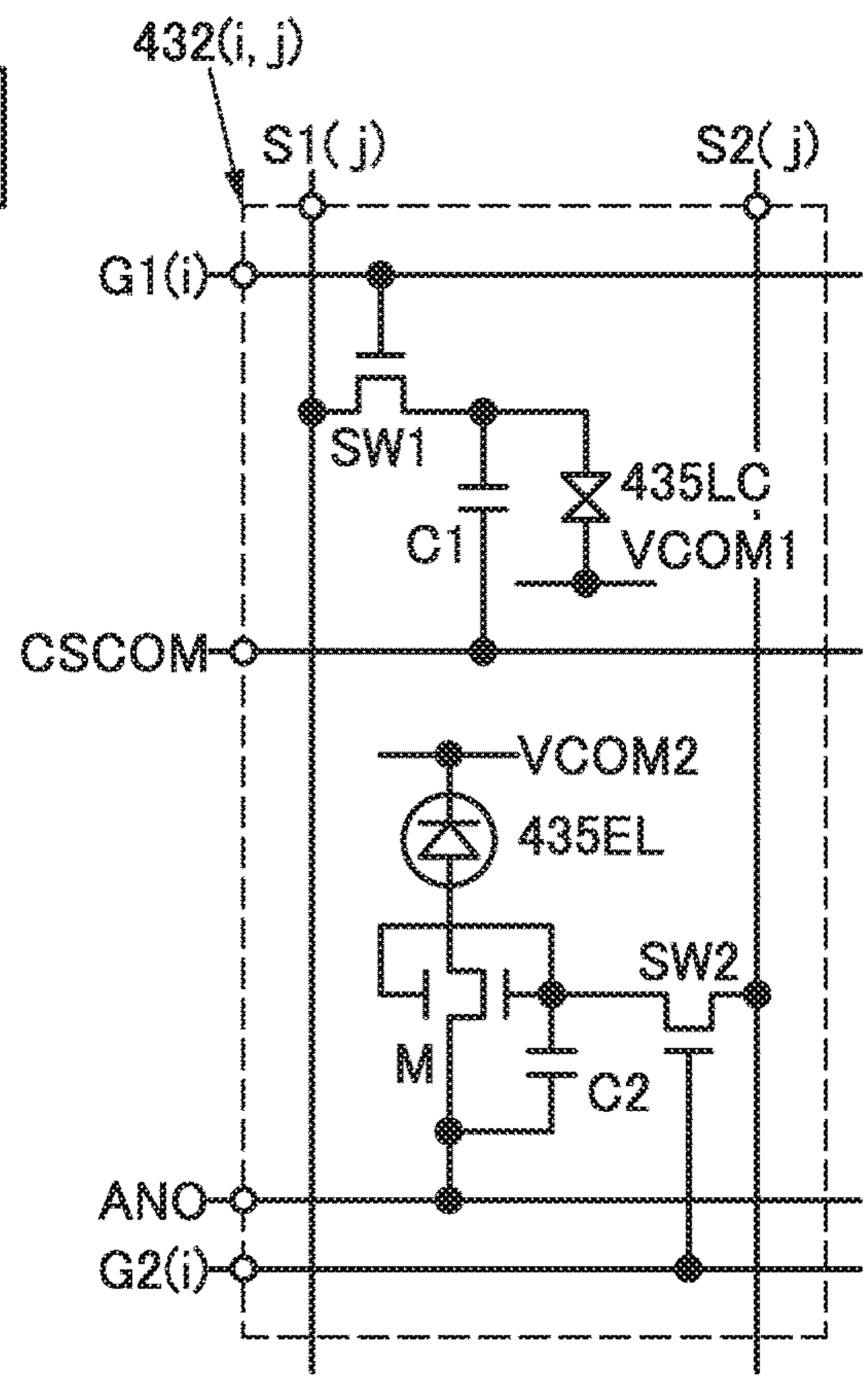


FIG. 18A

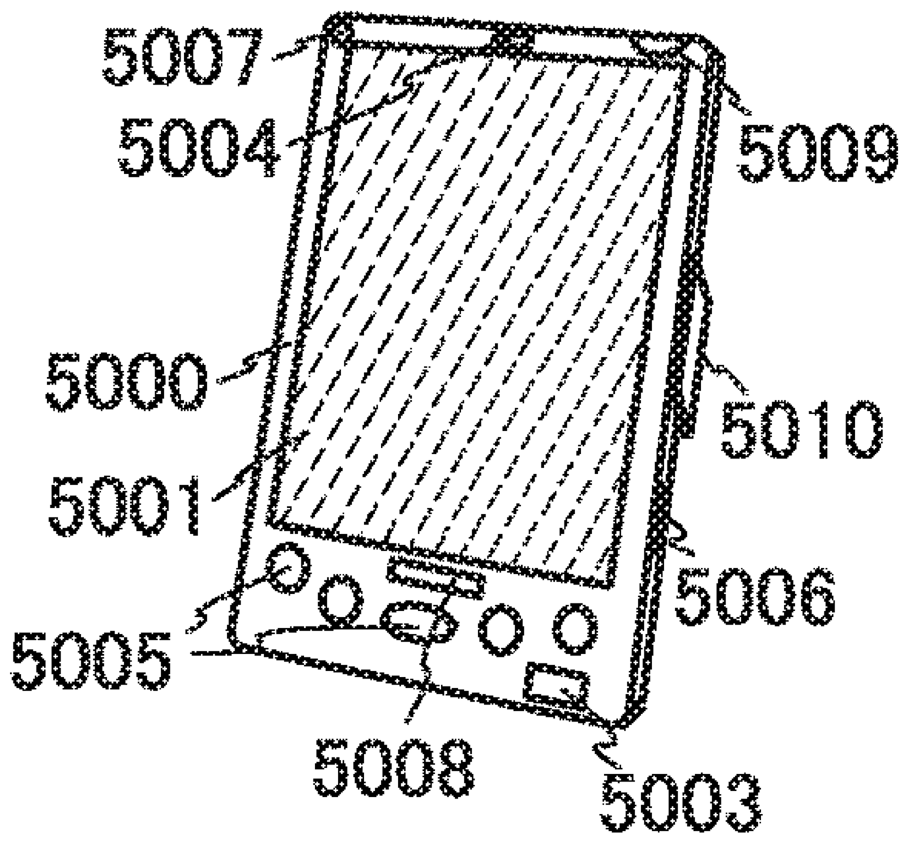


FIG. 18B

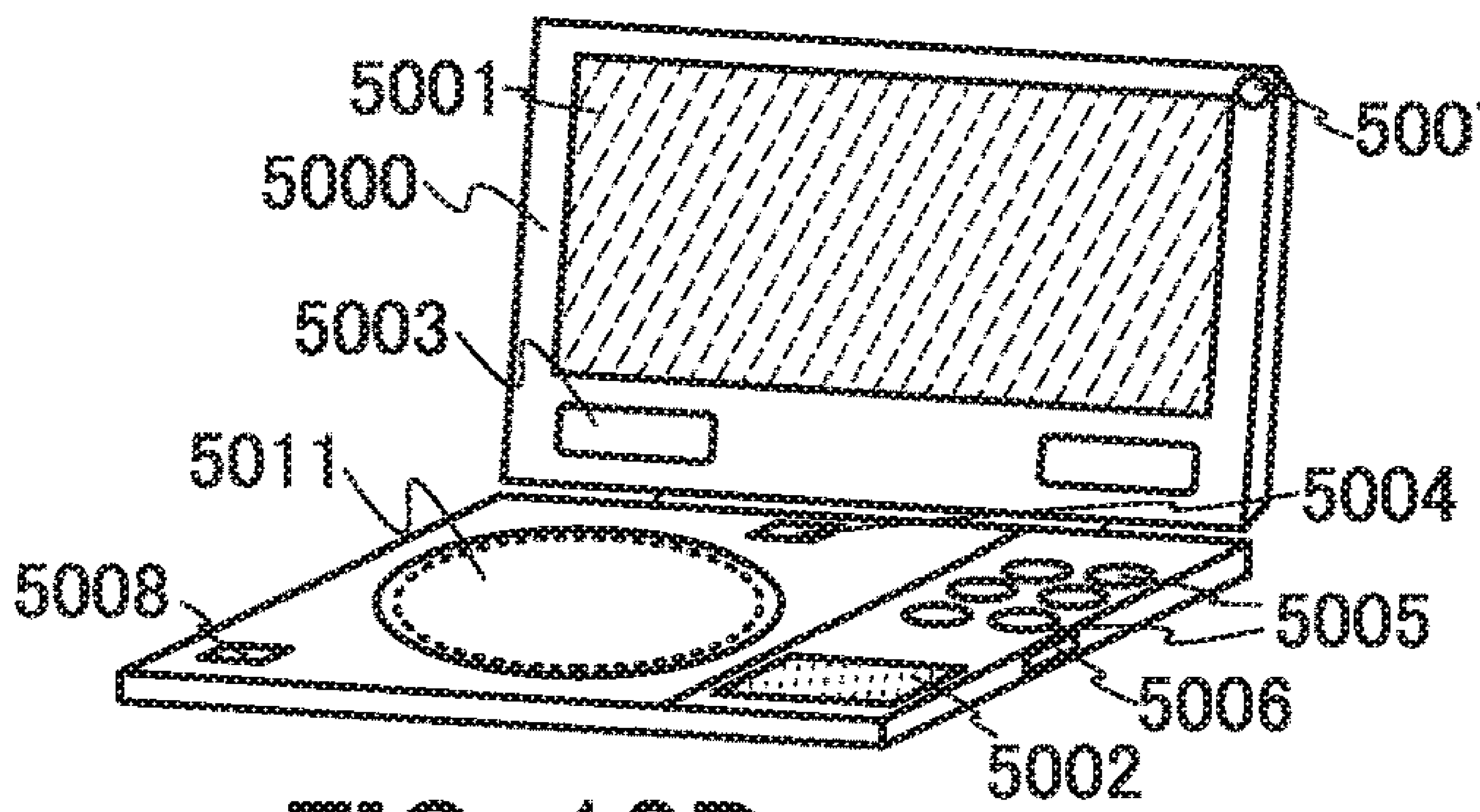


FIG. 18C

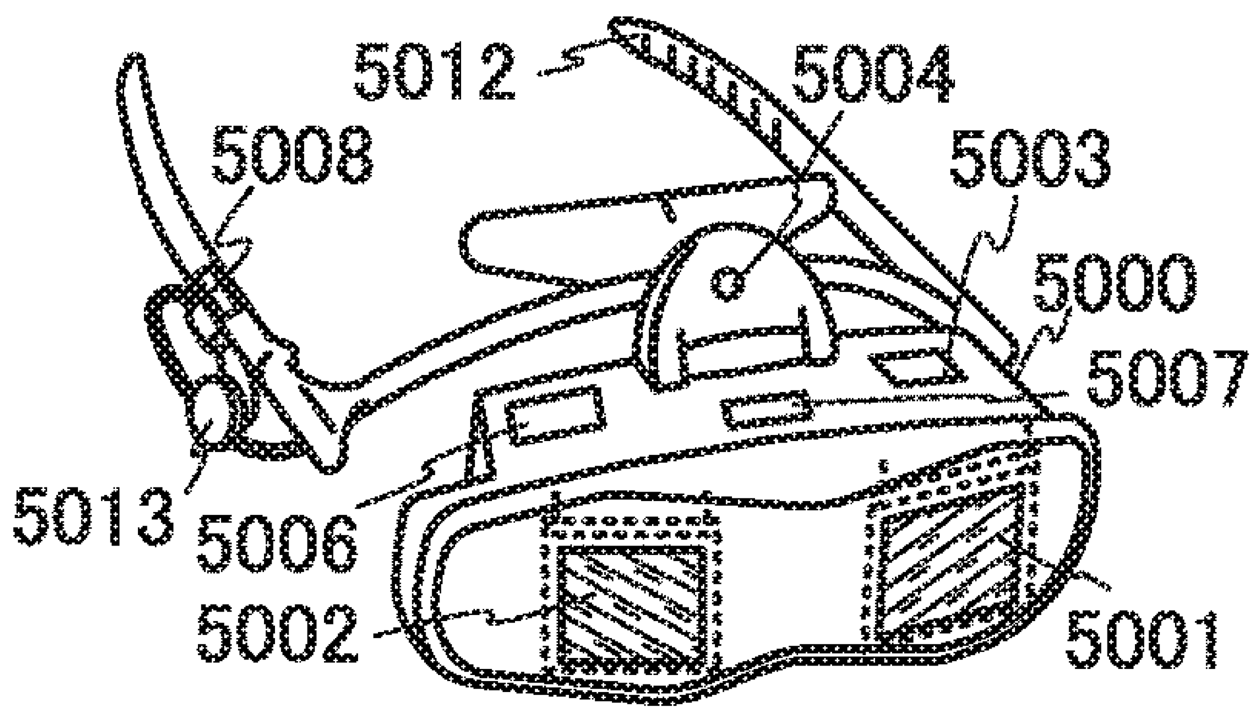


FIG. 18D

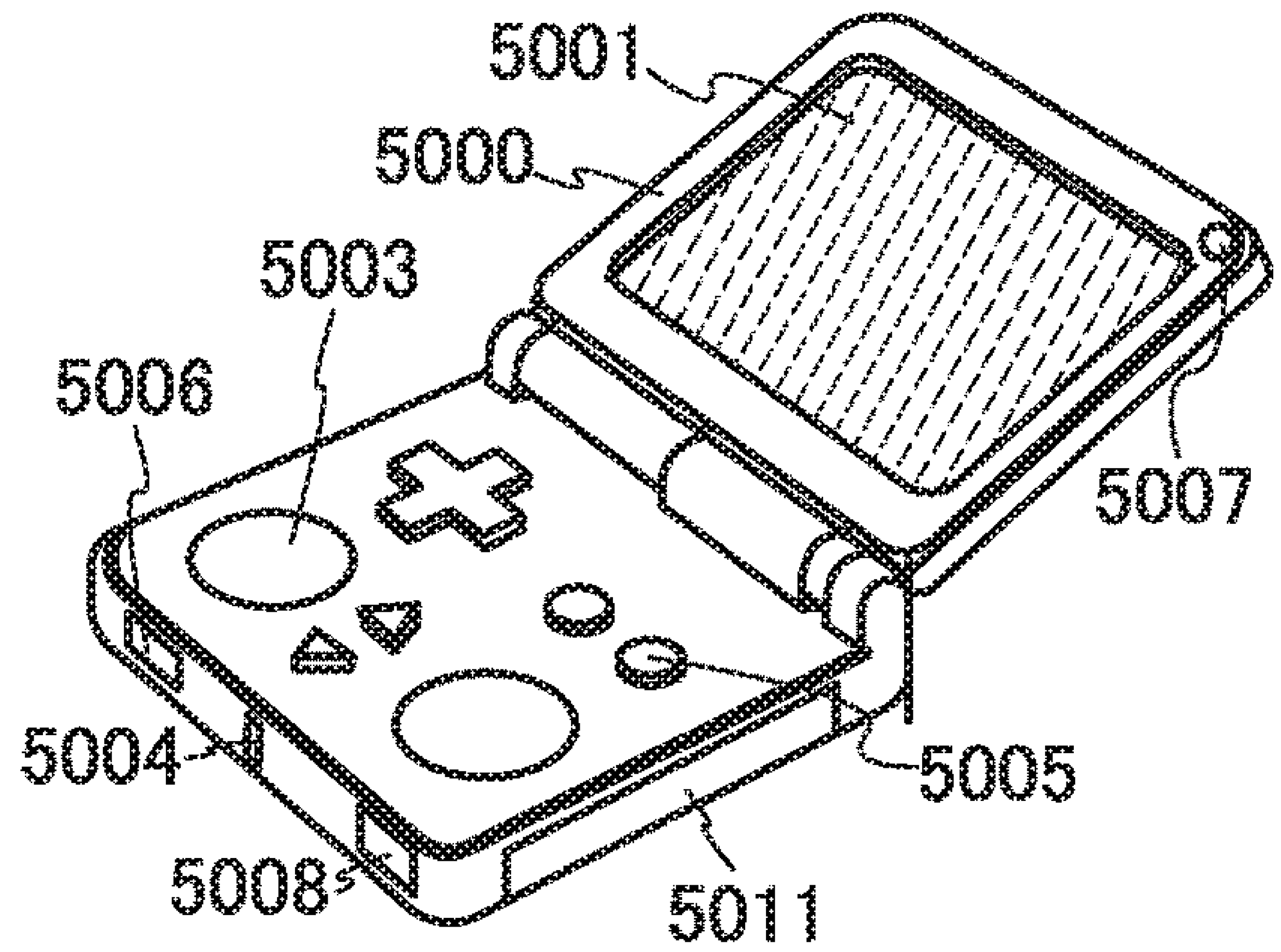


FIG. 18E

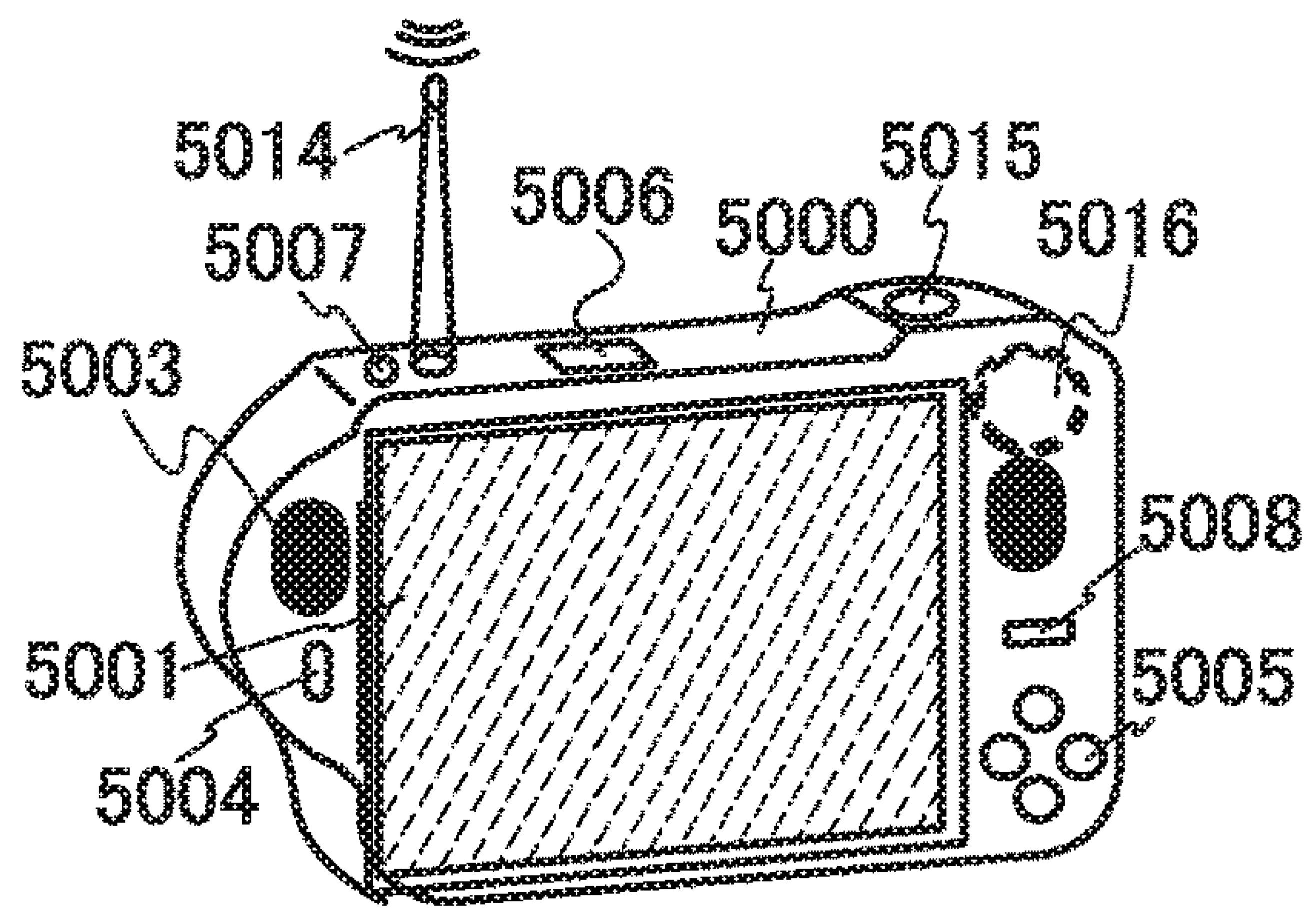


FIG. 18F

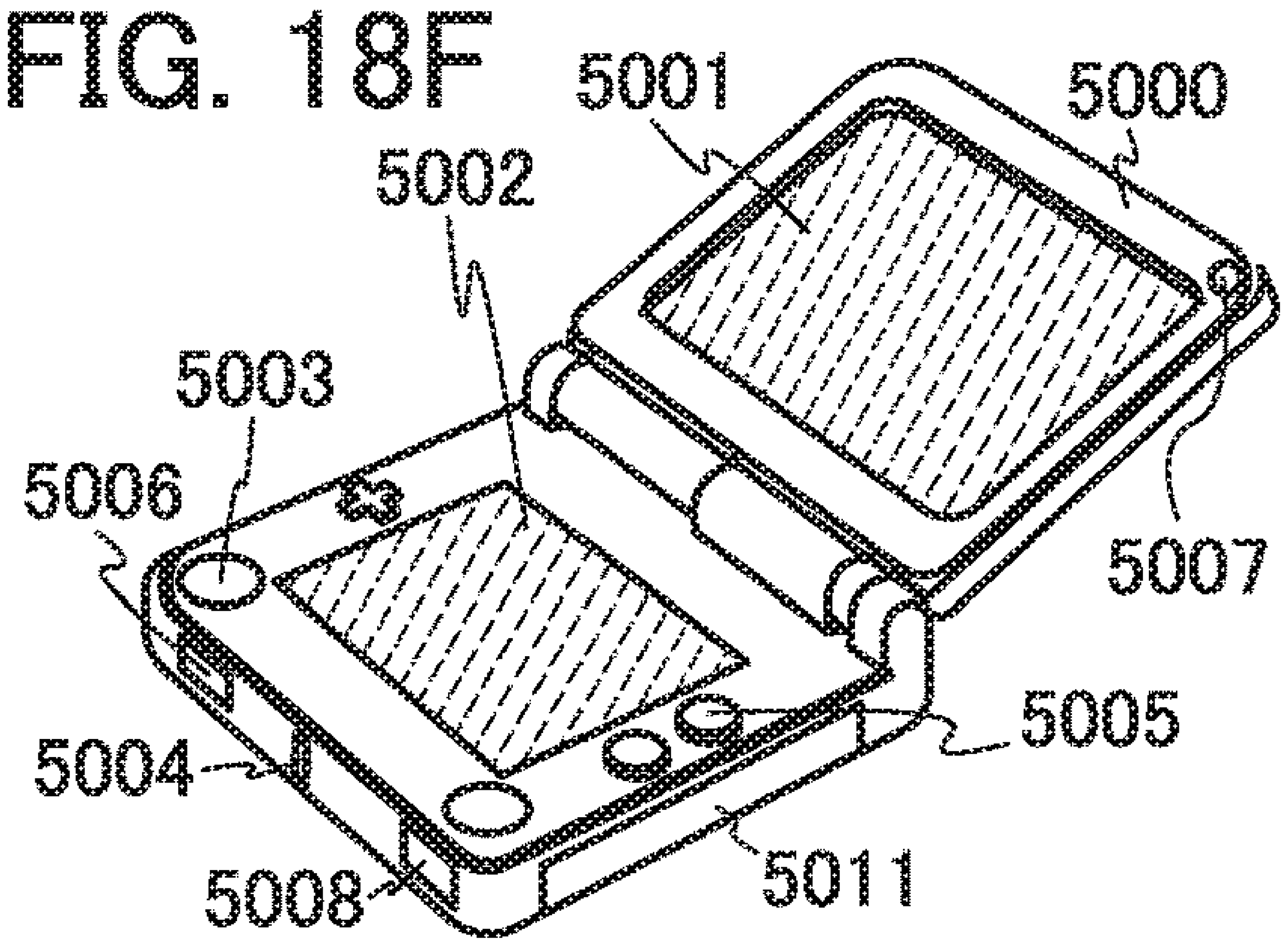


FIG. 18G

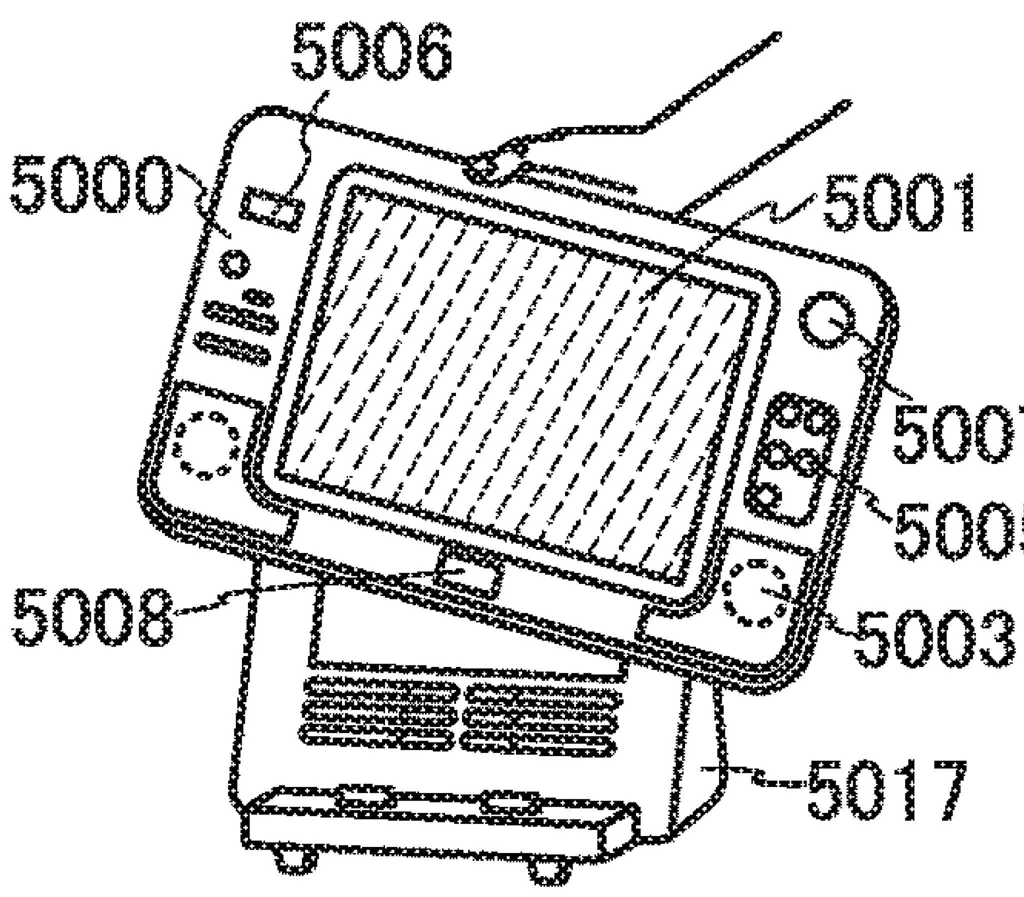
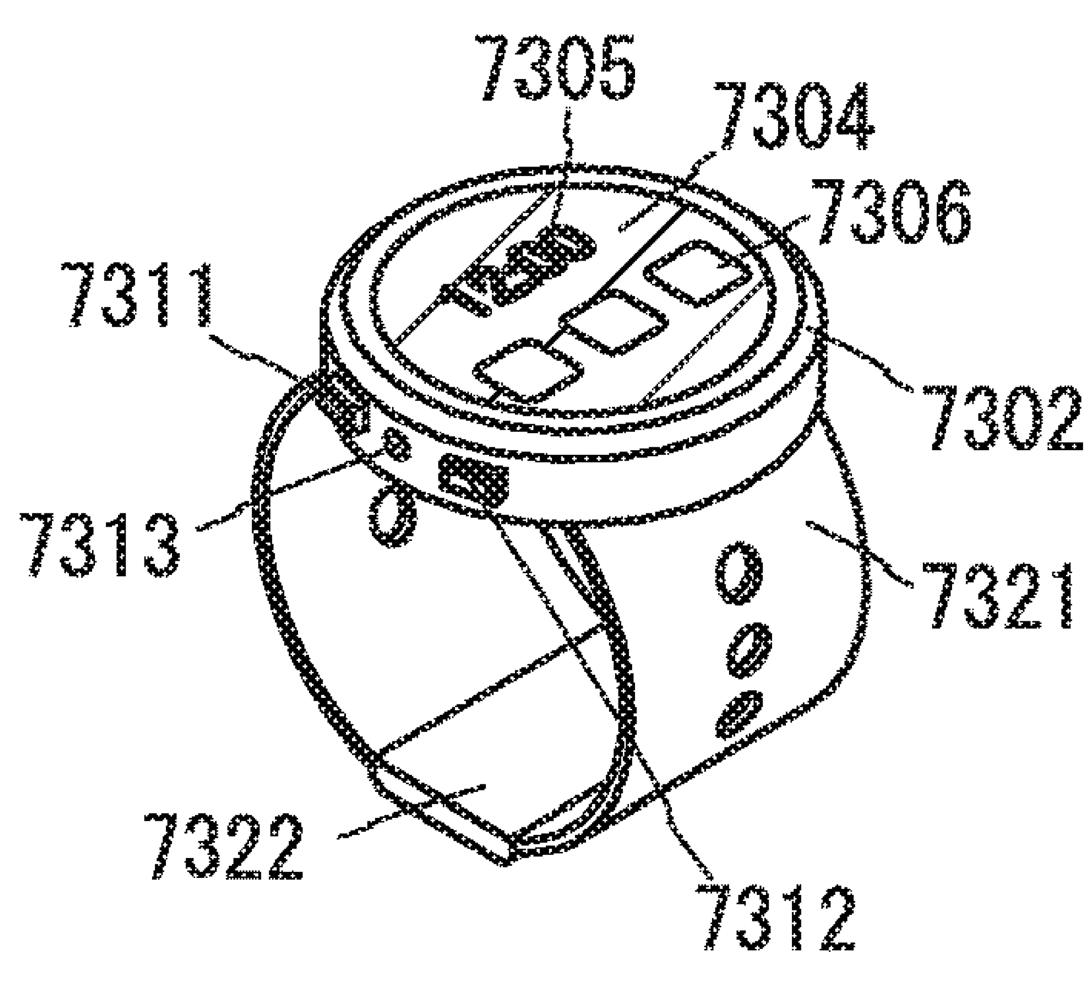


FIG. 18H



SEMICONDUCTOR DEVICE, MANUFACTURING METHOD THEREOF, AND SEPARATION APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

One embodiment of the present invention relates to a semiconductor device and a manufacturing method thereof. One embodiment of the present invention also relates to a separation apparatus and a stack manufacturing apparatus.

Note that in this specification, a semiconductor device generally means a device that can function by utilizing semiconductor characteristics. An electrooptic device, a semiconductor circuit, and an electronic device are all semiconductor devices.

Note that one embodiment of the present invention is not limited to the above technical fields. One embodiment of the invention disclosed in this specification and the like relates to an object, a method, or a manufacturing method. One embodiment of the present invention relates to a process, a machine, manufacture, or a composition of matter. Specifically, examples of the technical field of one embodiment of the invention disclosed in this specification and the like include a semiconductor device, a display device, a light-emitting device, a power storage device, a memory device, an electronic device, a lighting device, an input device (e.g., a touch sensor), an output device, an input/output device (e.g., a touch panel), a method for driving any of them, and a method for manufacturing any of them.

2. Description of the Related Art

Display devices used while being mounted on human bodies, such as display devices mounted on heads (e.g., head-mounted displays or glasses-type devices), have recently been proposed and are referred to as wearable displays. Furthermore, watch-type (also referred to as wrist-band-type) wearable devices are used through communication with tablet terminals.

Input devices such as a key board and a mouse are connected to a laptop computer. Tablet terminals have been in widespread use because they are more suitable for being carried around than laptop computers. In a tablet terminal which allows touch inputs, a touch panel is provided to overlap with a display portion. Input operation and the like can be performed by touching part of the touch panel overlapping with the screen of the display portion.

Various display devices have been test-fabricated, and an application to portable devices has particularly attracted attention. Glass substrates and quartz substrates are often used in recent years; however, they have disadvantages in that they are easily broken and they are heavy. In addition, increasing the size of glass substrates and quartz substrates is difficult, and glass substrates and quartz substrates are thus not suitable for mass production. For these reasons, forming transistors over flexible substrates, typically, flexible plastic films, is being attempted. When transistors are formed over plastic films, the process is limited to processes in which heating is not performed at temperatures higher than or equal to the heat-resistant temperatures of the plastic films.

Thus, technique in which an element formed over a glass substrate is separated from the substrate and transferred to another base, for example, a plastic film, has been proposed.

A separation and transfer technique with the use of a metal layer is proposed in Patent Document 1. In Patent Document

1, a technique in which a metal layer (Ti, Al, Ta, W, Mo, Cu, Cr, Nd, Fe, Ni, Co, Ru, Rh, Pd, Os, or Ir) is formed over a substrate and an oxide layer is stacked thereover is described. In this technique, when the oxide layer is formed, a metal oxide layer of the metal layer is formed at an interface between the metal layer and the oxide layer, and separation is carried out in a later step by utilizing this metal oxide layer.

In addition, a technique in which a metal layer in the periphery of a substrate is selectively etched, the left metal layer is irradiated with laser light, and a metal oxide layer is formed so as to carry out separation is described in Patent Document 1.

REFERENCE

Patent Document

[Patent Document 1] PCT International Publication No. WO2004/040648

SUMMARY OF THE INVENTION

As a method for manufacturing a device including a flexible film such as a plastic film, a technique has been developed in which a functional element such as a thin film transistor or an organic electroluminescence (hereinafter also referred to as EL) element is formed over a formation substrate (e.g., a glass substrate or a quartz substrate), and then the functional element is transferred to a flexible film. This technique needs a process of separating a layer to be separated including the functional element from the formation substrate (also referred to as a separation process).

In the present invention, a technique is disclosed in which a transistor formed using an oxide semiconductor film, a transistor formed using a polysilicon film, a transistor formed using an amorphous silicon film or the like, a transistor formed using an organic semiconductor film, a light-emitting element, or a passive element (such as a sensor element, an antenna, a resistor, or a capacitor), is separated from a glass substrate with light or heat.

One embodiment of the present invention relates to a flexible display device including an element and a method for manufacturing the flexible display device.

Although the transistor formed using an oxide semiconductor film, the transistor formed using an amorphous silicon film or the like, or the transistor formed using an organic semiconductor film can be formed directly on a plastic film, a dedicated manufacturing apparatus is required to handle a plastic film because it is softer than a glass substrate. When mass production is carried out, the manufacturing apparatus feeds plastic films in accordance with a roll-to-roll method.

In order to use a conventional manufacturing apparatus, a semiconductor element is sometimes provided over a plastic film in such a manner that the plastic film is fixed to a temporary substrate (e.g., a glass substrate), the semiconductor element is formed over the plastic film with the conventional manufacturing apparatus, and then the glass substrate is separated. A process for obtaining a flexible device in which a glass substrate is used for transportation and is finally separated in the above manner can also be used.

An object of one embodiment of the present invention is to provide a separation apparatus that enables easy separation in a large-area substrate.

Note that the descriptions of these objects do not disturb the existence of other objects. In one embodiment of the present invention, there is no need to achieve all the objects. Other objects will be apparent from and can be derived from the description of the specification, the drawings, the claims, and the like.

One embodiment of the present invention relates to a flexible display device including a semiconductor element and a method for manufacturing the flexible display device.

One embodiment of the present invention is a method for manufacturing a semiconductor device in which an oxide layer is formed over a light-transmitting substrate, a metal layer is selectively formed over the oxide layer, a resin layer is formed over the metal layer, an element layer is formed over the resin layer, a flexible film is fixed to the element layer, the resin layer and the metal layer are irradiated with light through the light-transmitting substrate, the light-transmitting substrate is separated, and a bottom surface of the metal layer is made bare.

In the above manufacturing method, there is no particular limitation on a material for the light-transmitting substrate as long as it transmits later-emitted light. For example, a glass substrate or a quartz substrate is used. In addition, the light-transmitting substrate can be reused because it is separated in the later step.

In the above manufacturing method, an insulating layer containing silicon such as a silicon oxide film or a silicon oxynitride film can be used as the oxide layer, for example. Alternatively, an oxide semiconductor film, an In-M-Zn oxide film (M is Al, Ti, Ga, Y, Zr, La, Ce, Nd, Sn, or Hf) (e.g., an IGZO film that is a metal oxide film containing In, Ga, and Zn) can be used as the oxide layer. A metal oxide film that contains In, Ga, and Zn can be removed after the separation of the glass substrate because the metal oxide film is easy to remove by a wet etching. In addition, the metal oxide film may be used as a surface protective layer for the bare metal layer at the time of transportation and be removed just before being connected to an external terminal, for example.

In the above manufacturing method, the metal layer can be formed using tungsten, molybdenum, chromium, copper, silver, gold, nickel, an alloy of any of the elements (e.g., tungsten nitride), or the like by a CVD method or a sputtering method. The metal layer is preferably formed using a material which is hardly oxidized or a material which is conductive even when oxidized because the metal layer is made bare to be connected to an external terminal.

In the above manufacturing method, light emitted from a laser light source is used. As the laser light source, a XeCl excimer laser (λ=308 nm) or an ultraviolet laser (λ=355 nm) can be used. It is preferable that a plurality of laser light sources be used, a large-sized substrate be irradiated with laser light, and a rectangular or linear irradiation region be formed with optical systems including lenses, which makes it possible to shorten the process time. Flash lamp light may be used instead of the laser light. The use of the lamp is effective because light irradiation for a large area of the large-sized substrate can be performed in a short time.

Through the above manufacturing method, a thin film device in which the metal layer electrically connected to an electrode of the element layer is not covered can be provided. This metal layer can be used as a terminal electrode which is connected to an external terminal such as an FPC.

Conventional separation methods have problems in a portion to which an external terminal is connected because the conventional methods almost do not include a method for making an electrode bare on an exposed separated surface. For example, when a glass substrate is separated after a separation layer is formed over the glass substrate, an element is formed over the separation layer, and a terminal electrode is formed, the separation is performed in a state where a fixed film substrate is also attached to the terminal electrode. Therefore, the process is complex in order to remove part of the film substrate to make the terminal electrode bare, possibly resulting in decrease in the yield. In addition, the glass substrate is separated after an FPC is connected to the terminal electrode, which possibly results in poor connection of the FPC.

In a separation method of one embodiment of the present invention, a metal layer to be a terminal electrode can be bare on a bottom surface of the thin film device when an element formation surface of the thin film device is regarded as a top surface; therefore, an external terminal such as an FPC can be connected to the metal layer after the glass substrate is separated. In addition, when the element formation surface of the thin film device is regarded as a top surface, the metal layer to be the terminal electrode can be bare on the bottom surface, so that the element and the terminal electrode can be placed at the position where they overlap with each other. Specifically, the terminal electrode can be provided in a region overlapping with a driver circuit, which enables the total area to be reduced and the thin film device to be compact.

In the above manufacturing method, the resin layer can be formed using a material selected from an epoxy resin, an acrylic resin, a polyimide resin, a polyamide resin, and a polyamide-imide resin. The resin layer is formed by a printing method, a droplet discharging method, a coating method using a coater apparatus, or the like. This resin layer can be regarded as a base or as a second flexible film opposed to the flexible film provided over the element layer.

When used as the second flexible film, the resin layer preferably forms a stack with an inorganic insulating film serving as a barrier layer for blocking entry of impurities such as water to the element.

Depending on the formation apparatus, the resin layer might be formed at a side surface of the substrate and might be attached to not only the side surface but also the bottom surface of the substrate. In this case, light irradiation is not sufficiently performed at the peripheral portion of the substrate and the peripheral portion of the substrate is fixed by the resin layer, so that the separation might become difficult. Thus, the resin layer formed on the side or bottom surface of the substrate is preferably removed in such a manner that side surface treatment is subjected to the substrate or a processing for cutting the substrate is performed before the substrate separation processing and the laser light irradiation are performed.

Alternatively, the resin layer formed on the side or bottom surface of the substrate may be removed in such a manner that side surface treatment is subjected to the substrate or a processing for cutting the substrate is performed after the laser light irradiation is performed and before the substrate separation processing is performed.

One embodiment of the present invention is a method for manufacturing a semiconductor device in which a resin layer is formed over a light-transmitting substrate, a barrier layer is formed over the resin layer, a layer including an element is formed over the barrier layer, a film is attached to the layer including the element, light irradiation is performed after side surface treatment is subjected to the substrate or a processing for cutting the substrate is performed, separation is started from the side surface of the substrate that is subjected to the side surface treatment or to the cutting processing, and the substrate is separated.

A separation apparatus for achieving the above manufacturing method is also one embodiment of the present invention. The separation apparatus has a function of dividing a process member including a first member and a second member, includes a support body supply unit, a support body hold unit, a direction changing mechanism, a substrate side surface treatment unit, a light irradiation unit, and a substrate separation unit. The substrate separation unit has a function of dividing the process member into the first member and the second member, and the direction changing mechanism has a function of changing a direction in which the support body is fed.

In the separation apparatus, the first member is a glass substrate and an oxide layer, and the second member is the metal layer, the resin layer, and the layer including the element.

It is preferable that the separation apparatus include a fixing mechanism. The fixing mechanism is configured to fix the second member at least part of which is separated from the first member.

It is preferable that the separation apparatus include a liquid supply mechanism. The liquid supply mechanism is configured to supply liquid (e.g., water, or an organic solvent) between the first member and the second member (or the separation surface).

It is preferable that the separation apparatus include a reel. The reel is located between the support body supply unit and the support body hold unit. A tape is bonded to one surface of the support body, and the reel is configured to wind up the tape.

It is preferable that the separation apparatus have an efficient structure in which light irradiation is performed through openings between a plurality of conveyor rollers. In this case, the width of the laser light irradiation region is made to be close to the substrate width.

In the separation method of this specification, a terminal electrode can be provided on a side opposed to a display surface because the terminal electrode can be bare on a separated surface. In the separation method of this specification, the terminal electrode can be bare on the separated surface, so that which substrate side to be used as the display surface of the panel can more freely selected. In addition, there are increased choices available: light-emitting elements (top- or bottom-emission elements), liquid crystal elements (transmissive or reflective elements), electronic ink, electrophoretic elements, and the like.

In the separation apparatus of this specification, the glass substrate can be efficiently separated and a semiconductor element can be provided over the plastic film.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIGS. **1**A to **1**E are cross-sectional views illustrating a manufacturing process of one embodiment of the present invention;

FIG. **2** is a perspective view of a display module, illustrating one embodiment of the present invention;

FIGS. **3**A to **3**C are perspective views of a separation apparatus, illustrating one embodiment of the present invention;

FIGS. **4**A to **4**C are cross-sectional schematic views of one embodiment of the present invention;

FIG. **5** is a cross-sectional schematic view of a separation apparatus of one embodiment of the present invention;

FIG. **6** is a perspective view illustrating part of a separation apparatus of one embodiment of the present invention;

FIG. **7** illustrates a structure of a display panel of an embodiment;

FIG. **8** illustrates a structure of a display panel of an embodiment;

FIG. **9** is a circuit diagram illustrating a pixel circuit of an embodiment;

FIGS. **10**A, **10**B**1**, and **10**B**2** illustrate structures of a display panel of an embodiment;

FIG. **11** illustrates a method for manufacturing a display panel of an embodiment;

FIGS. **12**A to **12**C illustrate a method for manufacturing a display panel of an embodiment;

FIG. **13** illustrates a method for manufacturing a display panel of an embodiment;

FIG. **14** illustrates a method for manufacturing a display panel of an embodiment;

FIG. **15** illustrates a structure of an input/output device of an embodiment;

FIGS. **16**A to **16**C are a block diagram and projection views illustrating structures of information processing devices of embodiments;

FIGS. **17**A to **17**C are block diagrams and a circuit diagram illustrating structures of display portions of embodiments; and

FIGS. **18**A to **18**H each illustrate an electronic device of an embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings. Note that the present invention is not limited to the description below, and it is easily understood by those skilled in the art that modes and details of the present invention can be modified in various ways. Furthermore, the present invention is not construed as being limited to the description in the embodiments described below.

Embodiment 1

An example of a method for manufacturing a display device of one embodiment of the present invention will be described with reference to FIGS. **1**A to **1**E, and FIG. **2**. Note that each of FIGS. **1**A to **1**E corresponds to a cross section of a peripheral circuit **132** along the dashed-dotted line A**1**-A**2** in FIG. **2** and a cross section of a display region **131** along the dashed-dotted line A**3**-A**4** in FIG. **2**.

First, an oxide layer **101** is formed over a light-transmitting substrate **100** (also referred to as "an element formation substrate").

As the substrate **100**, a glass substrate, a quartz substrate, a sapphire substrate, or the like can be used. As an example of a glass substrate, a barium borosilicate glass substrate, an aluminoborosilicate glass substrate, a soda lime glass substrate, or the like can be given.

The oxide layer **101** is formed using silicon oxide, silicon oxynitride, silicon nitride oxide, tungsten oxide, molybdenum oxide, gallium oxide, titanium oxide, or the like. The oxide layer **101** can be formed to have a single-layer structure or a stacked-layer structure using any of the materials. Alternatively, an In-M-Zn oxide film (M is Al, Ti, Ga, Y, Zr, La, Ce, Nd, Sn, or Hf) (e.g., an IGZO film that is a metal oxide film containing In, Ga, and Zn) can be used as the oxide layer **101**. Since laser light irradiation is performed later, a film having a property of transmitting laser light is preferably used. The thickness of the oxide layer **101** can be selected from a range of greater than or equal to 1 nm and less than or equal to 500 nm.

Next, metal layers **102***a* and **102***b* are selectively formed over the oxide layer **101**. The metal layers **102***a* and **102***b* are selectively formed in such a manner that a metal film is formed, a resist mask is formed over the metal film, and the metal film is selectively removed using the resist mask. The resist mask can be formed by a lithography method, a printing method, an inkjet method, or the like as appropriate. Formation of the resist mask by an inkjet method needs no photomask; thus, the manufacturing cost can be reduced.

The metal layers **102***a* and **102***b* can be formed using tungsten, molybdenum, chromium, copper, silver, gold, nickel, an alloy of any of the elements (e.g., tungsten nitride), or the like by a CVD method or a sputtering method. The metal layer **102***a* is preferably formed using a material which is hardly oxidized or a material which is conductive even when oxidized because the metal layer **102***a* is made bare to be connected to an external terminal. In this embodiment, tungsten is used. Each of the thicknesses of the metal layers **102***a* and **102***b* can be selected from a range of greater than or equal to 10 nm and less than or equal to 500 nm.

Subsequently, a resin layer **103** is formed over the metal layers **102***a* and **102***b*.

The resin layer **103** can be formed using an acrylic resin, a polyimide resin, a poly(methyl methacrylate) resin, a polycarbonate resin, a polyethersulfone resin, a polyamide resin, a cycloolefin resin, a polystyrene resin, a poly(amide imide) resin, a polypropylene resin, a polyester resin, a vinyl resin, an aramid resin, an epoxy resin, or the like. Alternatively, a mixture or a stack including any of these materials may be used.

Next, a barrier layer **104** is formed over the resin layer **103** (see FIG. **1**A).

The barrier layer **104** can prevent or reduce diffusion of impurity elements from the outside. The barrier layer **104** is preferably formed as a single layer or a multilayer using any of silicon nitride, silicon oxynitride, silicon nitride oxide, aluminum oxide, aluminum oxynitride, aluminum nitride oxide, and the like. The barrier layer **104** also can prevent or reduce diffusion of impurity elements from the resin layer **103**. The barrier layer **104** also can function as a light-blocking layer for preventing separation at an interface between the resin layer **103** and the barrier layer **104**, which is generated by light irradiation for the resin layer **103** under the barrier layer **104** when a semiconductor layer of the transistor is irradiated with laser light in a later step.

A layer to be separated including a transistor **105**, an electrode **109**, and the like is formed over the barrier layer **104**. The transistor **105** can be formed by a known formation method, and there is no particular limitation. In this embodiment, an amorphous silicon film is formed and then irradiated with laser light to be a polycrystalline silicon film, and the polycrystalline silicon film is used as the semiconductor layer. Although an example in which the polycrystalline silicon film is formed by laser light is described in this embodiment, one embodiment of the present invention is not limited thereto. The polycrystalline silicon film may be formed by heat processing at temperatures at which the resin layer can withstand.

When heat processing at temperatures higher than or equal to 410° C. is performed in the formation process of the transistor **105**, a metal oxide layer (not illustrated) which is likely to cause separation is formed anew at an interface between the metal layer **102***a* and the oxide layer **101** in some cases. In this embodiment, when a metal oxide layer containing tungsten oxide is formed at the interface between the metal layer **102***a* and the oxide layer **101**, separation can be performed without laser light irradiation to be performed in the later step, so that laser light irradiation for the metal layer **102***a* in the later step can be skipped.

An electrode **107** is electrically connected to the metal layer **102***a* through an opening formed by selectively etching an insulating layer **106**, the barrier layer **104**, and the resin layer **103**.

The electrode **109** is electrically connected to one electrode **110** of a light-emitting element. The electrode **109** can also be called a drain electrode which is electrically connected to a semiconductor layer of the transistor in the display region.

Over the insulating layer **106**, a partition **111** for separating the light-emitting elements is formed.

Next, an EL layer **112** and another electrode **113** of the light-emitting element are formed to complete the light-emitting element. This light-emitting element is a light-emitting element using electroluminescence (EL). Note that materials of the one electrode **110** of the light-emitting element and the other electrode **113** are selected as appropriate, so that the display device can also have a top-emission structure, a bottom-emission structure, or a dual-emission structure.

The EL layer **112** includes at least a light-emitting layer and may have a stacked structure including a functional layer in addition to the light-emitting layer. As the functional layer other than the light-emitting layer, a layer containing a substance having a high hole-injection property, a substance having a high hole-transport property, a substance having a high electron-transport property, a substance having a high electron-injection property, a bipolar substance (a substance having high electron- and hole-transport properties), or the like can be used. Specifically, functional layers such as a hole-injection layer, a hole-transport layer, an electron-transport layer, and an electron-injection layer can be used in combination as appropriate.

The light-emitting element can provide a variety of emission colors depending on the kinds of the light-emitting materials that are used for the EL layer **112**. The use of light-emitting elements that can provide the respective emission colors of red, green, and blue, for example, can achieve full color display. In addition, a plurality of light-emitting materials of different colors are used as the light-emitting material, whereby light emission having a broad spectrum or white light emission can also be obtained. The light-emitting element that can provide white light emission is used in combination with a color filter, whereby full color display can be achieved.

Next, a flexible film **115** is attached to the electrode **113** using an adhesive layer **114** (see FIG. **1**B). The flexible film **115** may be a stacked film including an optical film such as a polarizing film or a color filter including a coloring layer.

The adhesive layer **114** can be formed using a light curable adhesive, a reactive curable adhesive, a thermal curable adhesive, or an anaerobic adhesive. For example, an epoxy resin, an acrylic resin, a silicone resin, a phenol resin, an imide resin, a poly(vinyl chloride) (PVC) resin, a poly (vinyl butyral) (PVB) resin, or an ethylene-vinyl acetate (EVA) resin can be used. In particular, a material with low moisture permeability, such as an epoxy resin, is preferred. Alternatively, a two-component type resin may be used. Still alternatively, an adhesive sheet or the like may be used.

Next, the resin layer **103** is irradiated with light **210** that is transmitted through the substrate **100** (FIG. **1**C). As the light **210**, infrared light, visible light, or ultraviolet light emitted from a halogen lamp, a high pressure mercury lamp, or the like can be used. The wavelength of the light **210** is preferably greater than or equal to 400 nm and less than or equal to 1.2 μm, further preferably greater than or equal to 500 nm and less than or equal to 900 nm, or still further preferably greater than or equal to 500 nm and less than or equal to 700 nm. In this embodiment, a light source of a XeCl excimer laser (λ=308 nm) is used. It is preferable that a plurality of laser light sources be used, a large-sized substrate be irradiated with laser light, and a rectangular or linear irradiation region be formed with optical systems including lenses, which makes it possible to shorten the process time. Flash lamp light may be used instead of the laser light. The use of the flash lamp light source is effective because light irradiation for a large area of the large-sized substrate can be performed in a short time. A flash lamp light source and a laser light source may be used at the same time or used at different timings for irradiation.

A separation interface is formed at an interface between the resin layer **103** and the oxide layer **101** by light irradiation. In addition, a metal oxide layer (not illustrated) is formed at an interface between the oxide layer **101** and the metal layers **102***a* and **102***b*, whereby separation is promoted later.

When heating is performed at 410° C. or higher in advance of the laser light irradiation, laser light irradiation for a region where the metal layers **102***a* and **102***b* are formed is not necessarily performed because the metal oxide layer is already formed.

When a tungsten layer and an oxide layer are formed, separation can be performed without laser light irradiation for that region depending on the conditions. Accordingly, an area where the tungsten layer is selectively formed is increased, an area irradiated with laser light can be reduced. The tungsten layer may be provided at a region overlapping with an element which is not required to be irradiated with laser light because the tungsten layer can function as a light-blocking layer. In this embodiment, the metal layer **102***a* overlaps with a semiconductor layer of the transistor **105** and the metal layer **102***b* overlaps with a semiconductor layer **108**, whereby light emitted from the laser light source is blocked. The metal layer **102***b* may be in a floating state, have a fixed potential, or have the same potential as a gate of a transistor overlapping therewith. Note that when a polyimide resin is used as the resin layer **103**, most of laser light is absorbed by the resin layer. Therefore, laser light rarely reaches elements when the resin layer is thick. When the resin layer is thin and there is a possibility that laser light reaches the elements, tungsten is effectively used for a light-blocking film.

When the entire surface of the substrate is irradiated with laser light, a time for laser light scanning is disadvantageously increased as the size of the substrate is increased. The use of tungsten for the light-blocking film can reduce the time for the laser light treatment; therefore, the separation method in this specification can achieve an advantageous effect.

Next, the substrate **100** is separated at the interface between the oxide layer **101** and the resin layer **103** and at the interface between the oxide layer **101** and the metal layers **102***a* and **102***b* (see FIG. **1**D). As a separation method, mechanical force (a separation process with a human hand or a gripper, a separation process by rotation of a roller, ultrasonic waves, or the like) may be used.

FIG. **3**A illustrates an example of an apparatus for separation. In FIG. **3**A, the substrate **100** is provided over a fixing stage **230** so as to be in the uppermost position, and is fixed

with a plurality of suction jigs **241**. The suction jigs **241** each include a vertical movement mechanism and a suction portion.

The flexible film **115** is fixed in contact with a top surface of the fixing stage **230**. As the fixing stage **230**, a vacuum suction stage, or an electrostatic adsorption stage can be used, for example. Alternatively, the flexible film **115** may be fixed to the stage with a screwing jig or the like. At this time, the flexible film **115** is aligned and fixed in a predetermined position.

FIGS. **4**A to **4**C are examples of cross-sectional schematic views at the times when pretreatment of a separation process using suction jigs is performed and when the separation process is performed.

A process member preferably has a separation trigger on its side surface **198** before being set on the separation apparatus illustrated in FIGS. **3**A to **3**C. This separation trigger can be formed by cutting treatment, polishing treatment, laser light treatment, plasma treatment, partial etching treatment using a chemical solution such as an organic solvent or an etchant, for example. For the plasma treatment, a plasma treatment apparatus having a mechanism for generating plasma at a pressure near atmospheric pressure is used.

FIG. **4**A illustrates a stack as the process member which includes the substrate **100**, the oxide layer **101**, the resin layer **103**, the layer **199** including elements, and the flexible film **115**, and side surface treatment is subjected to the side surface **198**. Note that the pretreatment of the separation process is performed to improve the yield and is not necessarily performed.

After the side surface treatment is performed, the suction jigs **241** are made to be in contact with the substrate **100** to fix the substrate **100**. In addition, the flexible film **115** is fixed in contact with the fixing stage **230**. FIG. **4**B illustrates this state. A perspective view illustrating the process member that is set in the separation apparatus corresponds to FIG. **3**A.

Then, one or some of the suction jigs **241**, which are the nearest to the portion subjected to the side surface treatment, are picked up to cause separation. A perspective view illustrating the separation being performed corresponds to FIG. **3**B. The separation is started in the direction of an arrow **292**, and then continued in the direction of an arrow **293** illustrated in FIG. **3**C by tilting the surface of the substrate **100**.

FIG. **4**C illustrates a state in which the separation is completed.

The peripheral portion of the substrate may be cut before the separation or the light irradiation so that the resin layer on the peripheral portion of the substrate is removed. The resin layer sometimes adheres to the bottom surface of the substrate in addition to its side surface in the peripheral portion of the substrate. When the cutting is performed, separation can be smoothly performed if started from the cut portion.

When the metal layer that is formed using tungsten as described in this embodiment has a thickness of greater than or equal to 150 nm, separation can be performed between the oxide layer **101** and the metal layer. In the case where the thickness of the metal layer formed using tungsten is less than 150 nm, the oxide layer **101** and the metal layer are hardly separated from each other and separation is possibly performed from the top surface side of the metal layer.

Next, an anisotropic conductive connection layer **138** is formed, and the external electrode **124** for inputting electric power or a signal to the display device is formed over the anisotropic conductive connection layer **138** (see FIG. **1**E). The external electrode **124** is electrically connected to the metal layer **102***a* through the anisotropic conductive connection layer **138**. Consequently, electric power or a signal can be input to the display device. Note that an FPC can be used as the external electrode **124**. A metal wire can also be used as the external electrode **124**. Although the anisotropic conductive connection layer **138** may be used to connect the metal wire and the metal layer **102***a* to each other, the connection can be made by a wire bonding method without using the anisotropic conductive connection layer **138**. Alternatively, the metal wire and the metal layer **102***a* may be connected to each other by a soldering method.

The anisotropic conductive connection layer **138** can be formed using any of various kinds of anisotropic conductive films (ACF), anisotropic conductive pastes (ACP), and the like.

The anisotropic conductive connection layer **138** is formed by curing a paste-form or sheet-form material that is obtained by mixing conductive particles to a thermosetting resin or a thermosetting and light curable resin. The anisotropic conductive connection layer **138** exhibits an anisotropic conductive property by light irradiation or thermocompression bonding. As the conductive particles used for the anisotropic conductive connection layer **138**, for example, particles of a spherical organic resin coated with a thin-film metal such as Au, Ni, or Co can be used.

Although FIG. **1**E illustrates the metal layer **102***b* that is not covered, there is no limitation. A protective film may be attached using an adhesive layer to protect the metal layer **102***b* from static electricity or the like. The metal layer **102***b* in a floating state becomes unnecessary after performing a function of blocking light at the time of laser light irradiation. Thus, the metal layer **102***b* may be separated together with the glass substrate at the time of separation. Although a depressed portion is formed on the resin layer in this case, there is no particular problem. In contrast, the metal layer **102***a* is connected to the upper-layer wiring through an opening of the resin layer, and therefore is fixed to the resin layer firmly enough. In order to fix the metal layer **102***a* more firmly, it is preferable that the number of openings of the resin layer be increased or the area of the opening be increased so that the area that is in contact with the upper-layer wiring is increased.

FIG. **2** is a perspective view of a display module obtained through the above manufacturing process.

FIG. **2** illustrates a display module placed between the resin layer **103** and the flexible film **115**. In this embodiment, a surface where the flexible film **115** is provided corresponds to its display surface so that a top-emission structure is employed. The display module includes the display region **131** and the peripheral circuit **132**, and the display region **131** includes a plurality of pixels **170**. Each of the pixels **170** includes at least one light-emitting element. A plurality of light-emitting elements are formed in the display region **131**. A transistor for controlling the amount of light emitted from the light-emitting element is connected to each light-emitting element.

The peripheral circuit **132** includes a plurality of the transistors **105**. The peripheral circuit **132** has a function of determining which of the light-emitting elements in the display region **131** is supplied with a signal from the external electrode **124**.

The metal layer **102***a* is provided in a region partly overlapping with the peripheral circuit **132** and is electrically connected to the external electrode **124**, whereby an area to be a frame can be reduced.

This embodiment can be implemented in appropriate combinations with the configurations described in the other embodiments.

Embodiment 2

The separation apparatus of one embodiment of the present invention is described with reference to FIG. **5** and FIG. **6**.

In this embodiment, an example in which the first member **72** and the second member **71** are separated from each other by separating the first member **72** from the process member **70** is described. Note that the first member **72** and the second member **71** may be separated from each other by separating the second member **71** from the process member **70**.

The process member **70** has a sheet-like shape and includes the sheet-like first member **72** and the sheet-like second member **71**. The first member **72** and the second member **71** may each have a single-layer structure or a stacked-layer structure. In this embodiment, the first member **72** is a glass substrate and an oxide layer formed over the surface of the glass substrate. The second member **71** is a separation layer including a transistor and a flexible film.

The process member **70** preferably has a separation trigger formed by a side surface treatment or a cutting treatment before being set on the conveyor roller. In the cutting treatment, the process member **70**, mainly part of the glass substrate, is cut with a cutter or a dicer so as to have a size suitable for processing which corresponds to a separation apparatus. In the side surface treatment, the resin layer or the like on the side surface of the process member is embrittled or removed by polishing for the side surface of the process member with a substrate side surface treatment unit, light irradiation with a carbon dioxide gas laser (the central wavelength is approximately 10.6 μm), light irradiation with a femtosecond laser (the central wavelength is approximately 800 nm), ultrasonic wave irradiation, plasma irradiation, or the like. The treatment facilitates the separation at the interface between the first member **72** and the second member **71**. The second member **71** includes at least one of a functional circuit, a functional element, and a functional film, for example. For example, the second member **71** can include at least one of a pixel circuit, a pixel driver circuit, a display element, a color filter, and a moisture-proof film of a display device.

The separation apparatus in FIG. **5** includes a plurality of conveyor rollers (e.g., conveyor rollers **643**, **644**, and **645**), a mechanism for emitting laser light **651** through openings between the plurality of conveyor rollers (a light irradiation unit), a tape reel **602**, a first wind-up reel **603**, a direction changing roller **604**, and a press roller **606**.

In a mechanism in which irradiation of the laser light **651** is performed through openings between the plurality of conveyor rollers, a feed direction **650** of the process member **70** is the scanning direction of laser light; therefore, the feed speed is preferably controlled by controlling the rotational speed of the conveyor roller. Note that FIG. **6** illustrates an example of the mechanism for irradiation of the laser light **651**. In the perspective view in FIG. **6**, the process member **70** is irradiated with the laser light **651** through openings between the plurality of conveyor rollers from the laser light source **655**. A lens **652**, a mirror **653**, and an optical system **654** are placed so that the laser beam is focused on the interface between the first member **72** and the second member **71** and the laser light irradiation region becomes linear, rectangular, or elliptical at the interface. In this embodiment, the laser light irradiation region has a length of greater than or equal to 20 cm and less than or equal to 1 m. Laser light irradiation is performed intermittently or continuously depending on the scanning speed of the conveyor roller **643**, and the interface between the first member **72** and the second member **71** is ablated to form a separation trigger.

In addition, in the mechanism that performs irradiation of the laser light **651** as illustrated in FIG. **6**, the side surface of the process member **70** is irradiated. Accordingly, the above described side surface treatment can be concurrently performed by the laser light **651**, and the mechanism can also be called a substrate side surface treatment unit.

Although the number of the laser light sources **655** is one in FIG. **6**, a plurality of laser light sources may be provided depending on the area of the process member **70**, specifically the size of the glass substrate, and a plurality of the laser light irradiation regions may be arranged in a row. As the size of the glass substrate, the fifth generation (1000 mm×1200 mm or 1300 mm×1500 mm); the sixth generation (1500 mm×1800 mm); the seventh generation (1870 mm×2200 mm); the eighth generation (2200 mm×2500 mm); the ninth generation (2400 mm×2800 mm); the tenth generation (2880 mm×3130 mm), or the like can be given. A large-sized glass substrate is sometimes difficult to perform minute processing because the substrate is shrunk by heat treatment or the like in the process for manufacturing a semiconductor device. Therefore, when such a large-sized glass substrate is used as the substrate, the one with a small shrinkage is preferably used. For example, the substrate can be a large-sized glass substrate having an amount of shrinkage of less than or equal to 20 ppm, preferably less than or equal to 10 ppm, further preferably less than or equal to 5 ppm, which is measured after heat treatment is performed for one hour at preferably 450° C., further preferably 500° C. In addition, a large-sized glass substrate (e.g., the tenth generation glass substrate) is preferably divided in advance of laser light irradiation, and then carried to the mechanism in which irradiation of the laser light **651** is performed.

The tape reel **602** is an example of the support body supply unit. The tape reel **602** can feed a support body **601** in rolled sheet form. The speed at which the support body **601** is fed is preferably adjustable. When the speed is set relatively low, for example, failure in separation of the process member or a crack in a separated member can be inhibited.

The support body supply unit may feed the support body **601** continuously. The support body **601** can be fed continuously when there is no need of stopping feeding the support body **601** during the process. It is preferable to feed the support body **601** continuously because separation can be performed at a uniform speed and with a uniform force. Note that in the separation process, the separation is preferably performed successively without being stopped, and is further preferably performed with constant velocity. When the separation stops in the middle of the process and then resumes from the same region, distortion or the like occurs in the region, unlike in the case of successive separation. Thus, a minute structure of the region or the characteristics of an electronic device or the like located on the region are changed, which might influence display of a display device, for example.

The support body supply unit may feed the support body **601** intermittently. The support body **601** may be fed intermittently in the case where feeding of the support body **601** needs to be stopped during the process. Note that at least during separation, the support body **601** is preferably fed continuously for a higher yield of separation.

As the support body **601**, a film in rolled sheet form made of an organic resin, a metal, an alloy, glass, or the like can be used.

The support body **601** may be a member that is not a constituent of the device to be manufactured (e.g., flexible device), such as a carrier tape. The flexible device means a device including a flexible film substrate, for example, a device part of which is bendable or a device part of which is kept bent. Alternatively, the support body **601** may be a flexible substrate or the like, which is a member that is a constituent of the device to be manufactured, like the second member **71**.

The support body hold unit can wind up the support body **601**, can wind up the support body **601** and the second member **71**, or can hold an end portion of the support body **601**, for example. The first wind-up reel **603** is an example of the support body hold unit. The first wind-up reel **603** can wind up the support body **601**.

The tape reel **602** includes one of a pair of tension applying mechanisms. The first wind-up reel **603** includes the other of the pair of tension applying mechanisms. The pair of tension applying mechanisms can apply tension to the support body **601**.

The plurality of conveyor rollers are an example of the conveying mechanism. The plurality of conveyor rollers can convey the process member **70**. The mechanism for conveying the process member **70** is not limited to the conveyor roller and may be a different conveying mechanism such as a belt conveyor or a conveying robot. Alternatively, the process member **70** may be placed over a stage over the conveying mechanism.

The conveyor roller **643**, the conveyor roller **644**, and the conveyor roller **645**, each of which is one of the conveyor rollers that are lined up, are provided at predetermined intervals and rotate in the direction in which the process member **70** (or the second member **71**) is fed (the clockwise direction as indicated by solid arrows). The plurality of lined-up conveyor rollers are each rotated by a driving portion (e.g., a motor), which is not illustrated.

The direction changing roller **604** is an example of a direction changing mechanism. The direction changing roller **604** can change the feed direction of the support body **601**.

The support body **601** is bonded to the second member **71** by the press roller **606** and the conveyor roller **645**.

In FIG. **5**, the bottom edge of the direction changing roller **604** is located at a higher level than that of the bottom edge of the press roller **606**. Here, when at least part of the process member **70** is positioned between the direction changing roller **604** and the press roller **606**, a plane including a surface of the second member **71** is called a first plane. With the first plane taken into consideration, the shortest distance between the first plane and the direction changing roller **604** is longer than the shortest distance between the first plane and the press roller **606**.

Such a structure can prevent the support body **601** from being in contact with the second member **71** before reaching the press roller **606**. Accordingly, air bubbles can be inhibited from being trapped between the support body **601** and the process member **70**.

The press roller **606** is an example of the first structure body having a convex surface. The press roller **606** is rotated by a driving portion (e.g., a motor) which is not illustrated.

When the press roller **606** rotates, the force of peeling the first member **72** is applied to the process member **70**; thus, the first member **72** is peeled. At this time, the process member **70** has been irradiated with the laser light **651** and has a separation trigger, so that smooth separation is performed. Separation of the first member **72** starts from the separation trigger, that is, from the side surface of the process member **70**. As a result, the process member **70** is divided into the first member **72** and the second member **71**.

The mechanism for separating the first member **72** from the process member **70** is not limited to the press roller **606**, and a structure body having a convex surface (or a convex curved surface) is applicable. For example, a cylindrical (e.g., circular cylindrical, right circular cylindrical, elliptic cylindrical, or parabolic cylindrical) or spherical structure body can be used. Furthermore, a roller such as a drum type roller can be used, for example. Examples of the shape of the structure body include a column with a bottom surface whose boundary includes a curved line (e.g., a cylinder with a perfect circle-shaped bottom surface or an elliptic cylinder with an ellipse-shaped bottom surface), and a column with a bottom surface whose boundary includes a curved line and a straight line (e.g., a column with a semicircular bottom surface or a semi-elliptical bottom surface). If the shape of the structure body is any of such columns, the convex surface corresponds to a curved surface of the column.

As a material of the first structure body, a metal, an alloy, an organic resin, rubber, or the like can be used. The first structure body may have a space or a hollow inside. Examples of the rubber include natural rubber, urethane rubber, nitrile rubber, and neoprene rubber. In the case of using rubber, it is preferable to use a material unlikely to be charged by friction or separation or to take countermeasures to prevent static electricity. The press roller **606** illustrated in FIG. **5** includes, for example, a hollow cylinder **606***a* made of rubber or an organic resin and a cylindrical column **606***b* made of a metal or an alloy and located inside the cylinder **606***a*.

For example, the convex surface of the first structure body can have a radius of curvature of greater than or equal to 0.5 mm and less than or equal to 3000 mm. In the case where a film is separated, for example, the radius of curvature of the convex surface can be greater than or equal to 0.5 mm and less than or equal to 1000 mm, and specifically can be 150 mm, 225 mm, or 300 mm. As an example of the structure body having such a convex surface, a roller with a diameter of 300 mm, 450 mm, or 600 mm can be given. Note that a preferred radius of curvature of the convex surface depends on the thickness or the size of a process member.

When the radius of curvature of the convex surface is too small, an element included in the second member **71** which is peeled along the convex surface might be broken. For this reason, the radius of curvature of the convex surface is preferably greater than or equal to 0.5 mm.

When the radius of curvature of the convex surface is large, a substrate of glass, sapphire, quartz, silicon, or the like, which has low flexibility and high stiffness, can be peeled along the convex surface. For this reason, the radius of curvature of the convex surface is preferably greater than or equal to 300 mm, for example.

When the radius of curvature of the convex surface is too large, the size of the separation apparatus might be increased, which might limit the installation location. For this reason, the radius of curvature of the convex surface is preferably less than or equal to 3000 mm, further preferably less than or equal to 1000 mm, still further preferably less than or equal to 500 mm, for example.

A larger radius of curvature of the convex surface is preferable because the angle α at which the press roller **606** bends back the support body **601** can be more easily made large. For this reason, the radius of curvature of the convex surface is preferably greater than or equal to 300 mm, for example.

The rotation speed of the press roller **606** is preferably adjustable. By adjusting the rotation speed of the press roller **606**, the yield of separation can be further increased.

The press roller **606** and the plurality of conveyor rollers may be movable in at least one direction (e.g., upward and downward, rightward and leftward, or forward and backward). The distance between the convex surface of the press roller **606** and a supporting surface of the conveyor roller is preferably adjustable because separation can be performed on process members with various thicknesses.

FIG. **5** illustrates an example in which the angle α at which the press roller **606** bends back the support body **601** is an obtuse angle.

The roller **617** is an example of the second structure body with a convex surface. The radius of curvature of the convex surface included in the roller **617** can be, for example, less than or equal to the radius of curvature of the convex surface included in the press roller **606**, and preferably less than the radius of curvature of the convex surface included in the press roller **606**. The roller **617** can feed the support body **601** from the press roller **606** to the first wind-up reel **603** along the convex surface.

The roller **617** can apply tension to the support body **601** by moving the shaft of the roller **617**. That is, the roller **617** can also be referred to as a tension roller. Specifically, the roller **617** can pull the support body **601** in the feed direction changed with the press roller **606**.

Moving the shaft of the roller **617** enables the roller **617** to control the angle α at which the press roller **606** bends back the support body **601**.

Note that the roller **617** may be movable only in one direction as illustrated in FIG. **5**; alternatively, no roller **617** may be provided.

The roller **617** can bend back the support body **601** to change the feed direction of the support body **601**. For example, the feed direction of the support body **601** may be changed to the horizontal direction. Alternatively, the following structure may be employed: the roller **617** bends back the support body **601** to change the feed direction of the support body **601**; then, the feed direction of the support body **601** is further changed to the horizontal direction by a direction changing roller **607** (FIG. **5**) located between the roller **617** and the first wind-up reel **603**.

The diameters of the direction changing roller **604** and the roller **617** are not limited and, for example, may be smaller than the diameter of the first press roller **606**. Materials that can be used for the press roller **606** can be used for each of the direction changing roller **604** and the roller **617**.

The separation apparatus may include a guide roller for guiding the support body **601** to the first wind-up reel **603**. One guide roller may be provided, or a plurality of guide rollers may be provided. Like a guide roller **632** illustrated in FIG. **5**, the guide roller may be capable of applying tension to the support body **601**.

The separation tape **600** (also called separate film) may be bonded to at least one surface of the support body **601**. In this case, the separation apparatus preferably includes a reel that can wind up the separation tape **600** bonded to one surface of the support body **601**. The reel is located between the support body supply unit and the support body hold unit. Furthermore, the separation apparatus may include a guide roller **634**. The guide roller **634** can guide the separation tape **600** to a second wind-up reel **613**.

The separation apparatus may include a drying mechanism **614**. Since the functional element (e.g., a transistor or a thin-film integrated circuit) included in the second member **71** is vulnerable to static electricity, it is preferable that liquid be supplied to the interface between the first member **72** and the second member **71** before separation or that the separation be performed while liquid is supplied to the interface. Since watermarks might be formed if the liquid adhered to the second member **71** is vaporized, the liquid is preferably removed immediately after the separation. Thus, immediately after separated from the first member **72**, the second member **71** including a functional element is preferably blow-dried to remove a droplet left on the second member **71**. Therefore, generation of watermarks can be suppressed. A carrier plate **609** may be provided to prevent slack in the support body **601**.

Although the feed direction of the support body **601** may be perpendicular to the horizontal plane, the feed direction is preferably tilted relative to the horizontal plane for higher stability and less shaking of the support body **601** being fed.

During the process, a static eliminator included in the separation apparatus is preferably used at a position where static electricity might be generated. There is no particular limitation on the static eliminator, and for example, a corona discharge ionizer, a soft X-ray ionizer, an ultraviolet ionizer, or the like can be used.

For example, it is preferable that the separation apparatus be provided with an ionizer and static elimination be performed by spraying the second member **71** with air, a nitrogen gas, or the like from the ionizer to reduce adverse effects of static electricity on the functional element. It is particularly preferable to use the ionizer in a step of bonding two members to each other and a step of dividing one member. The separation apparatus illustrated in FIG. **5** includes an ionizer **639**, an ionizer **620**, an ionizer **621**, and an ionizer **622**.

For example, the process member **70** is preferably divided into the first member **72** and the second member **71** while the vicinity of the interface between the first member **72** and the second member **71** is irradiated with ions using the ionizer **639** to remove static electricity.

The separation apparatus may include a substrate load cassette and a substrate unload cassette. For example, the process member **70** can be supplied to the substrate load cassette. The substrate load cassette can supply the process member **70** to the conveying mechanism or the like. The second member **71** can be supplied to the substrate unload cassette.

The process member **70** may be conveyed from the substrate load cassette onto the guide roller with the conveying mechanism of the separation apparatus. The second member **71** over the guide roller may be conveyed to the substrate unload cassette with the conveying mechanism. In the case where the separation apparatus is connected to a different apparatus, the process member **70** may be conveyed from the different apparatus onto the guide roller with the conveying mechanism. In other words, the separation apparatus does not necessarily include the substrate load cassette. The second member **71** over the guide roller may be conveyed to a different apparatus with the conveying mechanism. In other words, the separation apparatus does not necessarily include the substrate unload cassette.

In the separation apparatus of one embodiment of the present invention, the conveyor rollers such as the conveyor rollers **643**, **644**, and **645**, the press roller **606**, and the like are driving rollers rotated by an electric motor or the like. The rotation speed of the tape reel **602** and that of the first wind-up reel **603** are also adjusted with a motor. These driving rollers, the tape reel **602**, and the first wind-up reel **603** adjust the moving speed and tension of the support body **601**. For example, a guide roller **631**, the guide roller **632**, a guide roller **633**, the guide roller **634**, a guide roller **635**, and a guide roller **636**, the direction changing roller **604**, and a tension roller **608** are driven rollers. Note that in one embodiment of the present invention, whether each roller is a driving roller or a driven roller is not limited to the above and can be determined as appropriate. The roller **617** may be a driving roller or a driven roller. There is no particular limitation on the number of each kind of roller included in the separation apparatus of one embodiment of the present invention.

In the separation apparatus of one embodiment of the present invention, the first member is separated from the second member in such a manner that a support body is bonded to a process member and the support body is pulled, as described above. Since the process member can be automatically divided with the use of the support body, the processing time can be shortened and the manufacturing yield of products can be improved.

For example, the process member has a structure in which a formation substrate and a functional layer are stacked in this order. The functional layer corresponds to the second member and the formation substrate corresponds to the first member. Here, the support body may be used as a support body of the functional layer. In other words, the support body is not necessarily separated from the second member. A flexible substrate is bonded to the functional layer exposed by being separated from the formation substrate with the use of an adhesive, whereby a flexible device in which the support body, the functional layer, and the flexible substrate are stacked in this order can be manufactured.

Alternatively, the process member has a structure in which a formation substrate, a functional layer, and a flexible substrate are stacked in this order, for example. The functional layer and the flexible substrate correspond to the second member and the formation substrate corresponds to the first member. Since the support body bonded to the flexible substrate is unnecessary after separation, the support body is peeled from the second member. Another flexible substrate is bonded to the functional layer exposed by being separated from the formation substrate with the use of an adhesive, whereby a flexible device in which the flexible substrate, the functional layer, and the flexible substrate are stacked in this order can be manufactured.

Here, when force is applied to the support body for separation of the support body, failure in separation or a crack in the second member might occur depending on the feed speed, feed direction, or the like of the support body.

A structure described below makes it possible to automatically separate the support body and the first member, which enables reduction in the processing time and improvement of the manufacturing yield of the products in the separation apparatus of one embodiment of the present invention.

The separation apparatus in FIG. **5** includes the tension roller **608** and the guide roller **635**.

The guide roller **635** guides the support body **601** to the first wind-up reel **603**.

The tension roller **608** is located between the roller **617** and the first wind-up reel **603**. The tension roller **608** can apply tension in the direction in which the support body **601** is bent back.

As a roller for guiding the support body **601** to the first wind-up reel **603**, at least one of the guide roller **635** and the tension roller **608** is preferably provided.

A first wedge-shaped member **611** is preferably provided in a position where the support body **601** is bent back with the guide roller **635** or the tension roller **608**. The first wedge-shaped member **611** may be fixed to the carrier plate **610**. The first wedge-shaped member **611** has a tapered portion. The angle formed by a flat surface of the carrier plate **610** and the tapered portion of the first wedge-shaped member **611** determines the direction in which the support body **601** is bent back.

The angle of the direction in which the support body **601** is bent back is preferably, but not limited to, an acute angle to facilitate separation of the first member **72** from the support body **601**.

A second wedge-shaped member **612** is fixed to a table **637**. The first wind-up reel **603** can wind up the support body **601** that has passed between the first wedge-shaped member **611** and the second wedge-shaped member **612**.

The table **637** has a flat surface. The second member **71** separated from the support body **601** is placed on the flat surface.

The flat surface of the carrier plate **610** is preferably positioned at a higher level than the flat surface of the table **637**. In other words, the flat surface of the carrier plate **610** and the flat surface of the table **637** are not on the same plane and are located at different levels in cross section. As long as the flat surfaces are located at different levels, the first wedge-shaped member **611** and the second wedge-shaped member **612** may overlap with each other or do not necessarily overlap with each other when seen from above. In the case where the first wedge-shaped member **611** and the second wedge-shaped member **612** overlap with each other, a tip of the second wedge-shaped member **612** is located below the first wedge-shaped member **611**.

In this manner, with the use of the separation apparatus of one embodiment of the present invention, the process member can be divided into the first member and the second member with a high yield. The separation apparatus of one embodiment of the present invention does not require a complicated structure and can be used for the separation of process members with a variety of sizes.

Separation can be performed by a worker manually but in that case, experience is required for a high speed and a high yield of separation. Thus, automation using the separation apparatus of one embodiment of the present invention is important. When separation of a process member is automated with the separation apparatus of one embodiment of the present invention, conveying and separation of the process member at a certain speed and separation with uniform force can be performed, which can inhibit failure of separation and crack caused in a separated member.

Note that one embodiment of the present invention is applicable to not only a separation apparatus but also a conveying apparatus or a bonding apparatus.

This embodiment can be combined with any of the other embodiments as appropriate.

Embodiment 3

In Embodiment 1, polycrystalline silicon is used as an example. In this embodiment, a display device is manufactured with the use of a transistor formed using an oxide semiconductor. The field effect mobility of the transistor formed using an oxide semiconductor can be higher than that of a transistor formed using an amorphous silicon film; thus, a peripheral circuit can be formed. In addition, the transistor formed using an oxide semiconductor can be formed at lower process temperatures than that formed using a polycrystalline silicon film; therefore, the manufacturing cost can be reduced.

FIG. **7** illustrates a structure of a display panel **700** of one embodiment of the present invention. FIG. **7** is a bottom view of the display panel **700** of one embodiment of the present invention.

FIG. **8** illustrates the structure of the display panel **700** of one embodiment of the present invention. FIG. **8** is a cross-sectional view taken along lines **X1**-**X2**, **X3**-**X4**, **X5**-**X6**, **X7**-**X8**, and **X9**-**X10** in FIG. **7**.

FIG. **9** illustrates the structure of the display panel **700** of one embodiment of the present invention. FIG. **9** is a circuit diagram illustrating a pixel circuit **530**(*i,j*) and a pixel circuit **530**(*i,j*+1) that can be used as pixel circuits included in the display panel **700** of one embodiment of the present invention.

FIGS. **10**A, **10**B**1**, and **10**B**2** illustrate the structure of the display panel **700** of one embodiment of the present invention. FIG. **10**A is a block diagram illustrating the arrangement of pixels, wirings, and the like that can be used in the display panel **700** of one embodiment of the present invention. FIGS. **10**B**1** and **10**B**2** are schematic views illustrating the arrangement of openings **751**H which can be used for the display panel **700** of one embodiment of the present invention.

The display panel in this embodiment includes a driver circuit GD, a driver circuit SD, and a display region **710** (see FIG. **7** and FIG. **10**A). The display region **710** includes a pixel **702**(*i,j*). The pixel **702**(*i,j*) is electrically connected to the signal line S**1**(*j*). Note that although FIG. **7** illustrates the display panel **700** in which the display region **710** is rectangular, the display panel **700** can have a circular display region **710**. In addition, the substrate of the display panel **700** of one embodiment of the present invention is a flexible film substrate, and is bendable along a portion between the driver circuit and the display region. A narrower frame can be achieved. The substrate bendable along the portion between the driver circuit and the display region is effective especially for a device having a small display region.

The pixel **702**(*i,j*) includes a first display element **750**(*i,j*), a first conductive film, a second conductive film, an insulating film **501**C, the pixel circuit **530**(*i,j*), and a second display element **550**(*i,j*) (see FIG. **8** and FIG. **9**).

The first conductive film is electrically connected to the first display element **750**(*i,j*) (see FIG. **8**). For example, the first conductive film can be used for a first electrode **751**(*i,j*) of the first display element **750**(*i,j*).

The second conductive film includes a region overlapping with the first conductive film. For example, the second conductive film can be used for a conductive film **512**B serving as a source electrode or a drain electrode of a transistor that can be used for a switch SW**1**.

The insulating film **501**C includes a region between the second conductive film and the first conductive film.

The pixel circuit **530**(*i,j*) is electrically connected to the second conductive film. For example, the transistor in which the second conductive film is used as the conductive film **512**B serving as a source electrode or a drain electrode can be used as the switch SW**1** of the pixel circuit **530**(*i,j*) (see FIG. **8** and FIG. **9**).

The second display element **550**(*i,j*) is electrically connected to the pixel circuit **530**(*i,j*).

The insulating film **501**C has an opening **591**A (see FIG. **8**).

The second conductive film is electrically connected to the first conductive film through the opening **591**A. For example, the conductive film **512**B is electrically connected to the first electrode **751**(*i,j*) which also serves as the first conductive film.

The pixel circuit **530**(*i,j*) is electrically connected to the signal line S**1**(*j*) (see FIG. **9**). Note that the conductive film **512**A is electrically connected to the signal line S**1**(*j*) (see FIG. **8** and FIG. **9**).

The pixel circuit **530**(*i,j*) of the display panel in this embodiment includes the switch SW**1**. The switch SW**1** includes a transistor that includes an oxide semiconductor.

The second display element **550**(*i,j*) of the display panel in this embodiment has a function of performing display in the same direction as the display direction of the first display element **750**(*i,j*). For example, in the drawing, an arrow **762** shows the direction in which the first display element **750**(*i,j*) displays images by controlling the intensity of external light reflection. In addition, an arrow **763** shows the direction in which the second display element **550**(*i,j*) displays images (see FIG. **8**).

In addition, the second display element **550**(*i,j*) of the display panel in this embodiment has a function of displaying images in a region surrounded by a region in which the first display element **750**(*i,j*) displays images (see FIG. **10**B**1** or **10**B**2**). Note that the first display element **750**(*i,j*) displays images in a region overlapping with the first electrode **751**(*i,j*), and the second display element **550**(*i,j*) displays images in a region overlapping with the opening **751**H.

The first display element **750**(*i,j*) of the display panel in this embodiment includes a reflective film having a function of reflecting incident light and has a function of controlling the intensity of reflected light. The reflective film has the opening **751**H. Note that for example, the first conductive film, the first electrode **751**(*i,j*), or the like can be used as the reflective film of the first display element **750**(*i,j*).

The second display element **550**(*i,j*) has a function of emitting light toward the opening **751**H.

The display panel in this embodiment includes the pixel **702**(*i,j*), a group of pixels **702**(*i*,**1**) to **702**(*i,n*), another group of pixels **702**(**1**,*j*) to **702**(*m,j*), and a scan line G**1**(*i*) (see FIG. **10**A). Note that i is an integer greater than or equal to 1 and less than or equal to m, j is an integer greater than or equal to 1 and less than or equal to n, and each of m and n is an integer greater than or equal to 1.

The display panel in this embodiment also includes a scan line G**2**(*i*), a wiring CSCOM, and a wiring ANO.

The group of pixels **702**(*i*,**1**) to **702**(*i,n*) include the pixel **702**(*i,j*) and are arranged in the row direction (the direction shown by the arrow R in drawings).

The other group of pixels **702**(**1**,*j*) to **702**(*m,j*) include the pixel **702**(*i,j*) and are arranged in the column direction (the direction shown by the arrow C in drawings) intersecting the row direction.

The scan line G**1**(*i*) is electrically connected to the group of pixels **702**(*i*,**1**) to **702**(*i,n*) arranged in the row direction.

The group of pixels **702**(**1**,*j*) to **702**(*m,j*) arranged in the column direction are electrically connected to the signal line S**1**(*j*).

For example, the pixel **702**(*i,j*+1) adjacent to the pixel **702**(*i,j*) in the row direction includes an opening in a position different from that of the opening **751**H in the pixel **702**(*i,j*+1) (see FIG. **10**B**1**).

For example, the pixel **702**(*i*+1,*j*) adjacent to the pixel **702**(*i,j*) in the column direction has an opening in a position different from that of the opening **751**H in the pixel **702**(*i,j*) (see FIG. **10**B**2**). Note that for example, the first electrode **751**(*i,j*) can be used for the reflective film.

In addition, the display panel in this embodiment includes a terminal **519**B and a conductive film **511**B (see FIG. **8**).

The insulating film **501**C includes a region between the terminal **519**B and the conductive film **511**B. The insulating film **501**C has an opening **591**B.

The terminal **519**B is electrically connected to the conductive film **511**B through the opening **591**B. In addition, the conductive film **511**B is electrically connected to the pixel circuit **530**(*i,j*). Note that for example, when the first electrode **751**(*i,j*) or the first conductive film is used as the reflective film, a surface serving as a contact of the terminal **519**B faces in the same direction as a surface of the first electrode **751**(*i,j*) that faces light incident on the first display element **750**(*i,j*).

Thus, power or signals can be supplied to the pixel circuit through the terminal. As a result, a novel display panel that is highly convenient or reliable can be provided.

The first display element **750**(*i,j*) of the display panel in this embodiment includes a layer **753** containing a liquid crystal material, the first electrode **751**(*i,j*), and a second electrode **752**. The second electrode **752** is positioned such that an electric field which controls the alignment of the liquid crystal material is generated between the second electrode **752** and the first electrode **751**(*i,j*).

The display panel in this embodiment also includes an alignment film AF**1** and an alignment film AF**2**. The alignment film AF**2** is provided such that the layer **753** containing a liquid crystal material is placed between the alignment film AF**1** and the alignment film AF**2**.

The second display element **550**(*i,j*) of the display panel in this embodiment includes a third electrode **551**(*i,j*), a fourth electrode **552**, and a layer **553**(*j*) containing a light-emitting organic compound.

The fourth electrode **552** includes a region overlapping with the third electrode **551**(*i,j*). The layer **553**(*j*) containing a light-emitting organic compound is provided between the third electrode **551** and the fourth electrode **552**. The third electrode **551**(*i,j*) is electrically connected to the pixel circuit **530**(*i,j*) at a connection portion **522**.

The pixel **702**(*i,j*) of the display panel in this embodiment includes a coloring film CF**1**, a light-blocking film BM, an insulating film **771**, and a functional film **770**P.

The coloring film CF**1** includes a region overlapping with the first display element **750**(*i,j*). The light-blocking film BM has an opening in a region overlapping with the first display element **750**(*i,j*).

The insulating film **771** is provided between the coloring film CF**1** and the layer **753** containing a liquid crystal material or between the light-blocking film BM and the layer **753** containing a liquid crystal material. The insulating film **771** can reduce unevenness due to the thickness of the coloring film CF**1**. Alternatively, impurities can be prevented from being diffused from the light blocking film BM, the coloring film CF**1**, or the like to the layer **753** containing a liquid crystal material

The functional film **770**P includes a region overlapping with the first display element **750**(*i,j*). The functional film **770**P is provided such that a substrate **770** is placed between the functional film **770**P and the first display element **750**(*i,j*).

The display panel in this embodiment also includes a substrate **570**, the substrate **770**, and a functional layer **520**.

The substrate **770** includes a region overlapping with the substrate **570**. The functional layer **520** is provided between the substrate **570** and the substrate **770**.

The functional layer **520** includes the pixel circuit **530**(*i, j*), the second display element **550**(*i,j*), an insulating film **521**, and an insulating film **528**.

The insulating film **521** is provided between the pixel circuit **530**(*i,j*) and the second display element **550**(*i,j*).

The insulating film **528** is provided between the insulating film **521** and the substrate **570**, and has an opening in a region overlapping with the second display element **550**(*i,j*). The insulating film **528** along the edge of the third electrode **551** can avoid a short circuit between the third electrode **551** and the fourth electrode **552**.

The display panel in this embodiment also includes a bonding layer **505**, a sealant **705**, and a structure body KB**1**.

The bonding layer **505** is provided between the functional layer **520** and the substrate **570** and has a function of bonding the functional layer **520** and the substrate **570**.

The sealant **705** lies between the functional layer **520** and the substrate **770** and has a function of bonding the functional layer **520** and the substrate **770**.

The structure body KB**1** is provided for making a predetermined gap between the functional layer **520** and the substrate **570**.

The display panel in this embodiment also includes a terminal **519**C, a conductive film **511**C, and a conductor CP.

The insulating film **501**C includes a region placed between the terminal **519**C and the conductive film **511**C. The insulating film **501**C has an opening **591**C.

The terminal **519**C is electrically connected to the conductive film **511**C through the opening **591**C. The conductive film **511**C is electrically connected to the pixel circuit **530**(*i,j*).

The conductor CP is placed between the terminal **519**C and the second electrode **752**, and electrically connects the terminal **519**C and the second electrode **752**. For example, a conductive particle can be used as the conductor CP.

The driver circuit GD is electrically connected to the scan line G**1**(*i*). The driver circuit GD includes a transistor MD, for example. In the transistor MD, the semiconductor film **508** is formed using an oxide semiconductor, for example. An In-M oxide (M is Ti, Ga, Sn, Y, Zr, La, Ce, Nd, or Hf) or an In-M-Zn oxide can be used for the semiconductor film **508**. In the case where the semiconductor film **508** is formed of an In-M-Zn oxide, it is preferable to use a target including a polycrystalline In-M-Zn oxide as the sputtering target. The use of the target including a polycrystalline In-M-Zn oxide facilitates formation of the semiconductor film **508** having crystallinity. Note that the atomic ratio of metal elements in the formed semiconductor film **508** varies within a range of ±40% as an error of the atomic ratio of metal elements of the above sputtering target. For example, when a sputtering target with an atomic ratio of In:Ga:Zn=4:2:4.1 is used, an atomic ratio of In:Ga:Zn in the semiconductor film **508** may be 4:2:3 or its vicinity. The semiconductor film **508** can have a stacked structure including two or more layers. When the semiconductor film **508** has a two-layer structure, for example, each thickness of the first oxide semiconductor film and the second oxide semiconductor film is greater than or equal to 3 nm and less than or equal to 200 nm, preferably greater than or equal to 3 nm and less than or equal to 100 nm, further preferably greater than or equal to 3 nm and less than or equal to 50 nm.

Specifically, a transistor including a semiconductor film that can be formed in the same process as the transistor included in the pixel circuit **530**(*i,j*) can be used as the transistor MD (see FIG. **8**).

The driver circuit SD is electrically connected to the signal line S**1**(*j*). The driver circuit SD is electrically connected to a terminal that can be formed in the same process as, for example, the terminal **519**B or the terminal **519**C with the use of a conductive material.

FIG. **11**, FIG. **12**A, FIG. **13**, and FIG. **14** each illustrate the structure of the display panel of one embodiment of the present invention in a manufacturing process. FIG. **11**, FIG. **12**A, FIG. **13**, and FIG. **14** are is cross-sectional views taken along lines X**1**-X**2**, X**3**-X**4**, X**5**-X**6**, X**7**-X**8**, and X**9**-X**10** in FIG. **7**.

<Method for Manufacturing Display Panel>

A method for manufacturing a display panel described in this embodiment includes the following steps.

First, a process substrate **510** where an oxide layer is formed is prepared. A metal film is formed over the oxide layer, and then the metal film is selectively etched.

As the process substrate, a glass substrate, quartz substrate, sapphire substrate, or plastic substrate that is capable of transmitting laser light in the later process can be used. The oxide layer **510**W is formed using silicon oxide, silicon oxynitride, silicon nitride oxide, tungsten oxide, molybdenum oxide, gallium oxide, titanium oxide, or the like. The oxide layer **510**W can be formed to have a single-layer structure or a stacked-layer structure using any of the materials. Alternatively, an In-M-Zn oxide film (M is Al, Ti, Ga, Y, Zr, La, Ce, Nd, Sn, or Hf) (e.g., an IGZO film that is a metal oxide film containing In, Ga, and Zn) can be used as the oxide layer **510**W. In this embodiment, as an oxide layer over and in contact with the glass substrate, an IGZO film is used. Note that a compound including In, Ga, Zn, and O is also known as IGZO. Typical examples of IGZO include a crystalline compound represented by $InGaO_3(ZnO)_{m1}$ (m1 is a natural number) and a crystalline compound represented by $In_{(1+x0)}Ga_{(1-x0)}O_3(ZnO)_{m0}$ ($-1 \le x0 \le 1$; m0 is a given number). For the metal film formed over the oxide layer, tungsten, molybdenum, chromium, copper, silver, gold, nickel, an alloy of any of the elements (e.g., tungsten nitride), or the like may be used; in this embodiment, molybdenum is used.

The above metal film formed by etching becomes the first electrode **751**(**0** capable of functioning as a first conductive film and a wiring or electrode formed using the same layer. Depending on a material used for the oxide layer and conditions for etching the metal film, the bare oxide layer is also removed in some cases. In this embodiment, the bare oxide layer is also removed at the time of etching the metal film.

Next, a resin layer **754** is formed. The resin layer **754** may be formed using an organic material such as polyimide, polyester, polyolefin, polyamide, polycarbonate, or an acrylic resin. In this embodiment, polyimide is used for the resin layer **754**. Note that molybdenum that is used for the first electrode **751**(*i,j*) is easy to peel, and is covered with the resin layer **754** so that the first electrode **751**(*i,j*) is prevented from being peeled in the processes.

Next, an insulating film **501**C functioning as a barrier layer is formed over the resin layer **754** (see FIG. **11**).

The insulating film **501**C can be formed to have a single-layer structure or a multi-layer structure using an oxide material such as aluminum oxide, magnesium oxide, silicon oxide, silicon oxynitride, gallium oxide, germanium oxide, yttrium oxide, zirconium oxide, lanthanum oxide, neodymium oxide, hafnium oxide, or tantalum oxide; a nitride material such as silicon nitride, silicon nitride oxide, aluminum nitride, or aluminum nitride oxide; or the like. The insulating film **501**C may have, for example, a two-layer structure of silicon oxide and silicon nitride or a five-layer structure in which materials selected from the above are combined. The insulating film **501**C can be formed by a sputtering method, a CVD method, a thermal oxidation method, a coating method, a printing method, or the like.

The insulating film **501**C can prevent or reduce diffusion of impurity elements from the outside. The insulating film **501**C is preferably formed using an insulating film having low water permeability. For example, the water vapor transmittance of the insulating film with low water permeability is lower than or equal to 1×10^{-5} g/m^2×day, preferably lower than or equal to 1×10^{-6} g/m^2×day, further preferably lower than or equal to 1×10^{-7} g/m^2×day, still further preferably lower than or equal to 1×10^{-8} g/m^2×day.

In this embodiment, a silicon oxynitride film having a thickness of approximately 200 nm is used as the insulating film **501**C.

Next, the insulating film **501**C and the resin layer **754** are selectively etched to form the opening **591**A, the opening **591**B, and the opening **591**C.

The pixel circuit and the second conductive film (including a wiring or electrode formed using the same layer as the second conductive film) which overlaps with the opening **591**A are formed (see FIG. **11** and FIG. **12**A).

FIG. **12**B is an enlarged view of the transistor MD and the transistor M. FIG. **12**C is an enlarged view of the switch SW**1**. For example, the conductive film **512**B of the transistor which can be used in the switch SW**1** can be used as the second conductive film (see FIG. **12**C).

The first conductive film (the first electrode **751**(*i,j*) and the second conductive film (the conductive film **512**B) can be electrically connected to each other using another conductive film including a region overlapping with the opening **591**A. For example, a conductive film that can be formed in the same process as the conductive film **504** can be used as the another conductive film.

A second display element **550**(*i,j*) that is electrically connected to the pixel circuit **530**(*i,j*) is formed.

Next, a substrate **570** is provided with the bonding layer **505** placed therebetween (see FIG. **13**). The transistor MD, the transistor M, the switch SW**1**, the display element **550**, and the like are between the substrate **510** and the substrate **570**.

In this embodiment, a flexible film is used as the substrate **570**.

Next, the process substrate (substrate **510**) is separated (see FIG. **14**).

Specifically, separation is performed after or during laser light irradiation by a method using laser light (specifically, a laser ablation method) or the like, for example. The separation apparatus described in Embodiment 1 or 2 is used for the separation. FIG. **14** illustrates the substrate **510** where the oxide layer is formed and the resin layer that are separated from each other. Although a portion in the resin layer where the first conductive film is not formed is actually projected, it is not emphasized or illustrated because the oxide layer is thin.

Next, an alignment film AF**1** is formed adjacently to a conductive film **751***a* and the insulating film **501**C.

A film containing soluble polyimide that is used as the alignment film AF**1** is formed by a printing method, for example. In the case where the film containing soluble polyimide is used, the temperature of heat transferred to the second display element **550**(*i,j*) in formation of the alignment film AF**1** can be lower than that when a method using a precursor of polyimide, such as a polyamic acid, is employed. As a result, the productivity of the display panel can be improved. Thus, a manufacturing method for a novel display panel that is highly convenient or reliable can be provided.

Next, the first display element **750**(*i,j*) is formed (see FIG. **8**). In this embodiment, a substrate formed using a resin material is used as the substrate **770**. In addition, the use of the substrate formed using the resin material as the substrate **770** can provide a display panel that is resistant to shocks from the outside and hardly broken. The device can be compact by bending part of the substrate **770**.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 4

In this embodiment, the structure of an input/output device of one embodiment of the present invention will be described with reference to FIG. **15**.

FIG. **15** is an exploded view of a structure of an input/output device **800**.

The input/output device **800** includes a display panel **806** and a touch sensor **804** having a region overlapping with the display panel **806**. Note that the input/output device **800** can function as a touch panel.

The input/output device **800** is provided with a driver circuit **810** for driving the touch sensor **804** and the display panel **806**, a battery **811** for supplying power to the driver circuit **810**, and a housing where the touch sensor **804**, the display panel **806**, the driver circuit **810**, and the battery **811** are stored.

<<Touch Sensor **804**>>

The touch sensor **804** includes a region overlapping with the display panel **806**. Note that an FPC **803** is electrically connected to the touch sensor **804**.

For the touch sensor **804**, a resistive touch sensor, a capacitive touch sensor, or a touch sensor using a photoelectric conversion element can be used, for example.

Note that the touch sensor **804** may be used as part of the display panel **806**. For example, a transistor of the touch sensor and a transistor connected to the display element may be formed on the same substrate.

<<Display Panel **806**>>

For example, the display panel described in Embodiment 1 can be used as the display panel **806**. A plastic film is used as the substrate. The plastic film can be bent partly to be compact. Note that an FPC **805** and the like are electrically connected to the display panel **806**.

<<Driver Circuit **810**>>

As the driver circuit **810**, a power supply circuit or a signal processing circuit can be used, for example. Power supplied from the battery or an external commercial power supply may be utilized.

The signal processing circuit has a function of outputting a video signal, a clock signal, and the like.

The power supply circuit has a function of supplying predetermined power.

<<Housing>>

An upper cover **801**, a lower cover **802** which fits the upper cover **801**, and a frame **809** which is stored in a region surrounded by the upper cover **801** and the lower cover **802** can be used for the housing, for example.

The frame **809** has a function of protecting the display panel **806**, a function of blocking electromagnetic waves generated by the operation of the driver circuit **810**, or a function as a radiator plate.

Metal, a resin, an elastomer, or the like can be used for the upper cover **801**, the lower cover **802**, or the frame **809**.

<<Battery **811**>>

The battery **811** has a function of supplying power.

Note that a functional member such as a polarizing plate, a retardation plate, or a prism sheet can be used for the input/output device **800**.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

Embodiment 5

In this embodiment, a structure of an information processing device of one embodiment of the present invention will be described with reference to FIGS. **16**A to **16**C and FIGS. **17**A and **17**B.

FIG. **16**A is a block diagram illustrating the structure of an information processing device **400**. FIGS. **16**B and **16**C are each a projection view illustrating an example of an external view of the information processing device **400**.

FIG. **17**A is a block diagram illustrating the configuration of a display portion **430**. FIG. **17**B is a block diagram illustrating the configuration of a display portion **430**B. FIG. **17**C is a circuit diagram illustrating the configuration of a pixel **432**(*i,j*).

Structure Example of Information Processing Device

The information processing device **400** in this embodiment includes an arithmetic device **410** and an input/output device **420** (see FIG. **16**A).

The arithmetic device **410** is configured to receive positional information P**1** and supply image information V and control information.

The input/output device **420** is configured to supply the positional information P**1** and receive the image information V and the control information.

The input/output device **420** includes the display portion **430** that displays the image information V and an input portion **440** that supplies the positional information P**1**.

The display portion **430** includes a first display element and a second display element overlapping with the first display element. The display portion **430** further includes a first pixel circuit for driving the first display element and a second pixel circuit for driving the second display element.

The input portion **440** is configured to detect the position of a pointer and supply the positional information P**1** determined on the basis of the position.

The arithmetic device **410** is configured to determine the moving speed of the pointer on the basis of the positional information P**1**.

The arithmetic device **410** is configured to determine the contrast or brightness of the image information V on the basis of the moving speed.

The information processing device **400** in this embodiment includes the input/output device **420** that supplies the positional information P**1** and receives the image information V and the arithmetic device **410** that receives the positional information P**1** and supplies the image information V. The arithmetic device **410** is configured to determine the contrast or brightness of the image information V on the basis of the moving speed of the positional information P**1**.

With this structure, eyestrain on a user caused when the display position of image information is moved can be reduced, that is, eye-friendly display can be achieved. Moreover, the power consumption can be reduced and excellent visibility can be provided even in a bright place exposed to direct sunlight, for example. As a result, a novel information processing device that is highly convenient or reliable can be provided.

One embodiment of the present invention includes the arithmetic device **410** or the input/output device **420**.

The arithmetic device **410** includes an arithmetic unit **411** and a memory portion **412**. The arithmetic device **410** further includes a transmission path **414** and an input/output interface **415** (see FIG. **16**A).

The arithmetic unit **411** has a function of, for example, executing a program.

The memory portion **412** has a function of storing a program executed by the arithmetic unit **411**, initial information, setting information, an image, or the like.

Specifically, a hard disk, a flash memory, a memory including a transistor including an oxide semiconductor, or the like can be used for the memory portion **412**.

The input/output interface **415** includes a terminal or a wiring and is configured to supply and receive information. For example, the input/output interface **415** can be electrically connected to the transmission path **414** and the input/output device **420**.

The transmission path **414** includes a wiring and is configured to supply and receive information. For example, the transmission path **414** can be electrically connected to the input/output interface **415**. In addition, the arithmetic unit **411** and the storage portion **412** can be electrically connected to the input/output interface **415**.

The input/output device **420** includes a display portion **430**, an input portion **440**, a sensor portion **450**, or a communication portion **490**.

The display portion **430** includes a display region **431**, a driver circuit GD, and a driver circuit SD (see FIG. **17**A). For example, the display panel in Embodiment 1 can be used. Thus, the power consumption can be reduced.

A display region **431** includes a plurality of pixels **432**(*i*,**1**) to **432**(*i,n*) arranged in a row direction, a plurality of pixels **432**(**1**,*j*) to **432**(*m,j*) arranged in a column direction, scan lines G**1**(*i*) and G**2**(*i*) which are electrically connected to the plurality of pixels **432**(*i*,**1**) to **432**(*i,n*), and the signal line S**1**(*j*) and the signal line S**2**(*j*) which are electrically connected to the plurality of pixels **432**(*i,j*) to **432**(*m,j*). Note that i is an integer greater than or equal to 1 and less than or equal to m, j is an integer greater than or equal to 1 and less than or equal to n, and each of m and n is an integer greater than or equal to 1.

Note that the pixel **432**(*i,j*) is electrically connected to the scan line G**1**(*i*), the scan line G**2**(*i*), the signal line S**1**(*j*), the signal line S**2**(*j*), the wiring ANO, the wiring CSCOM, the wiring VCOM**1**, and the wiring VCOM**2** (see FIG. **17**C).

The display portion can include a plurality of driver circuits. For example, the display portion **430**B can include a driver circuit GDA and a driver circuit GDB (see FIG. **17**B).

The driver circuit GD is configured to supply a selection signal on the basis of the control information.

For example, the driver circuit GD is configured to supply a selection signal to one scan line at a frequency of 30 Hz or higher, preferably 60 Hz or higher, on the basis of the control information. Accordingly, moving images can be smoothly displayed.

For example, the driver circuit GD is configured to supply a selection signal to one scan line at a frequency of lower than 30 Hz, preferably lower than 1 Hz, further preferably less than once per minute, on the basis of the control information. Accordingly, a still image can be displayed while flickering is suppressed.

For example, in the case where a plurality of driver circuits is provided, the driver circuits GDA and GDB may supply the selection signals at different frequencies. Specifically, the selection signal can be supplied at a higher frequency to a region on which moving images are smoothly displayed than to a region on which a still image is displayed in a state where flickering is suppressed.

The driver circuit SD is configured to supply an image signal on the basis of the image information V.

The pixel **432**(*i,j*) includes a first display element **435**LC and a second display element **435**EL overlapping with the first display element **435**LC. The pixel **432**(*i,j*) further includes a pixel circuit for driving the first display element **435**LC and a pixel circuit for driving the second display element **435**EL (see FIG. **17**C).

<<First Display Element **435**LC>>

For example, a display element having a function of controlling light reflection or transmission can be used as the first display element **435**LC. For example, a combined structure of a polarizing plate and a liquid crystal element or a MEMS shutter display element can be used. The use of a reflective display element can reduce power consumption of a display panel. Specifically, a reflective liquid crystal display element can be used as the display element **435**LC.

The first display element **435**LC includes a first electrode, a second electrode, and a liquid crystal layer. The liquid crystal layer contains a liquid crystal material whose orientation is controlled by voltage applied between the first electrode and the second electrode. For example, the orientation of the liquid crystal material can be controlled by an electric field in the thickness direction (also referred to as the vertical direction), the horizontal direction, or the diagonal direction of the liquid crystal layer.

<<Second Display Element **435**EL>>

A display element having a function of emitting light can be used as the second display element **435**EL, for example. Specifically, an organic EL element can be used as the second display element **435**EL.

Specifically, an organic EL element which emits white light can be used as the second display element **435**EL. Alternatively, an organic EL element which emits blue light, green light, or red light can be used as the second display element **435**EL.

<<Pixel Circuit>>

A circuit having a function of driving the first display element **435**LC or the second display element **435**EL can be used as the pixel circuit.

A switch, a transistor, a diode, a resistor, an inductor, a capacitor, or the like can be used in the pixel circuit.

For example, one or a plurality of transistors can be used as a switch. Alternatively, a plurality of transistors connected in parallel, in series, or in combination of parallel connection and series connection can be used as a switch.

<<Transistor>>

For example, a semiconductor film formed in the same process can be used for transistors in the driver circuit and the pixel circuit.

For example, bottom-gate transistors, top-gate transistors, or the like can be used.

For example, a manufacturing line for a bottom-gate transistor including an amorphous silicon film as a semiconductor film can be easily remodeled into a manufacturing line for a bottom-gate transistor including an oxide semiconductor as a semiconductor. Furthermore, for example, a manufacturing line for a top-gate transistor including a polysilicon film as a semiconductor film can be easily remodeled into a manufacturing line for a top-gate transistor including an oxide semiconductor as a semiconductor.

For example, a transistor including a semiconductor containing an element belonging to Group 14 can be used. Specifically, a semiconductor containing silicon can be used for a semiconductor film. For example, single crystal silicon, a polysilicon film, a microcrystalline silicon film, or an amorphous silicon film can be used for the semiconductor film of the transistor.

Note that the temperature for forming a transistor using a polysilicon film in a semiconductor film is lower than the temperature for forming a transistor using single crystal silicon in a semiconductor film.

In addition, the transistor using a polysilicon film in a semiconductor film has higher field-effect mobility than the transistor using an amorphous silicon film in a semiconductor film, and therefore enables a higher aperture ratio of pixel. Moreover, pixels arranged at extremely high density, a gate driver circuit, and a source driver circuit can be formed over the same substrate. As a result, the number of components included in an electronic device can be reduced.

In addition, the transistor using a polysilicon film as a semiconductor film has higher reliability than the transistor using an amorphous silicon film as a semiconductor film.

For example, a transistor including an oxide semiconductor can be used. Specifically, an oxide semiconductor containing indium or an oxide semiconductor containing indium, gallium, and zinc can be used for a semiconductor film.

For example, a transistor having a lower leakage current in an off state than a transistor using an amorphous silicon film for a semiconductor film can be used. Specifically, a transistor that uses an oxide semiconductor for a semiconductor film can be used.

Accordingly, the pixel circuit can hold an image signal for a longer time than a pixel circuit including a transistor that uses an amorphous silicon film for a semiconductor film. Specifically, the selection signal can be supplied with a frequency of lower than 30 Hz, preferably lower than 1 Hz, and further preferably less than once per minute while flickering is suppressed. Consequently, eyestrain on a user of the information processing device can be reduced, and power consumption for driving can be reduced.

<<Input Portion **440**>>

Any of a variety of human interfaces or the like can be used as the input portion **440** (see FIG. **16**A).

For example, a keyboard, a pointing device, a touch sensor, a microphone, a camera, or the like can be used as the input portion **440**. Note that a touch sensor having a region overlapping with the display portion **430** can be used. An input/output device that includes the display portion **430** and a touch sensor having a region overlapping with the display portion **430** can be referred to as a touch panel.

For example, a user can make various gestures (e.g., tap, drag, swipe, and pinch in) using his/her finger as a pointer on the touch panel.

The arithmetic device **410**, for example, analyzes information on the position, track, or the like of the finger on the touch panel and determines that a specific gesture is supplied when the analysis results meet predetermined conditions. Therefore, the user can supply a certain operation instruction associated with a certain gesture by using the gesture.

For instance, the user can supply a "scrolling instruction" for changing a portion where image information is displayed by using a gesture of touching and moving his/her finger on the touch panel.

<<Sensor Portion **450**>>

The sensor portion **450** is configured to acquire information P**2** by detecting the surrounding state.

For example, a camera, an acceleration sensor, a direction sensor, a pressure sensor, a temperature sensor, a humidity sensor, a proximity sensor, an illuminance sensor, or a global positioning system (GPS) signal receiving circuit can be used as the sensor portion **450**.

For example, when the arithmetic device **410** determines that the ambient light level measured by an illuminance sensor of the sensor portion **450** is sufficiently higher than the predetermined illuminance, image information is displayed using the first display element **435**LC. When the arithmetic device **410** determines that the ambient light level measured by the illuminance sensor is dim, image information is displayed using the first display element **435**LC and the second display element **435**EL. When the arithmetic device **410** determines that the ambient light level measured by the illuminance sensor is dark, image information is displayed using the second display element **435**EL.

Specifically, an image is displayed with a reflective liquid crystal element and/or an organic EL element depending on the ambient brightness.

Thus, image information can be displayed in such a manner that, for example, a reflective display element is used in an environment with strong external light and a self-luminous display element is used in a dim environment. As a result, a novel information processing device that has lower power consumption and is highly convenient or reliable can be provided.

For example, a sensor that is configured to measure the chromaticity of ambient light can be used in the sensor portion **450**. Specifically, a CCD camera or the like can be used. Thus, white balance can be adjusted depending on the chromaticity of ambient light sensed by the sensor portion **450**.

Specifically, in the first step, imbalance disruption of white balance of ambient light is measured.

In the second step, the light intensity of a color which is insufficient in an image to be displayed by the first display element using reflection of ambient light is estimated.

In the third step, ambient light is reflected by the first display element, and light is emitted from the second display element so that light of the insufficient color is supplemented, whereby an image is displayed.

In this manner, display can be performed with adjusted white balance by utilizing light reflected by the first display element and light emitted from the second display element. Thus, a novel information processing device which can display an image with low power consumption or with adjusted white balance and which is highly convenient and reliable can be provided.

<<Communication Portion **490**>>

The communication portion **490** has a function of supplying and acquiring information to/from a network.

Image information may be generated on the basis of information of the usage environment of the information processing device acquired by the sensor portion **450**. For example, user's favorite color can be used as the background color of the image information depending on the acquired ambient brightness or the like (see FIG. **16**B).

Image information may be generated on the basis of received information delivered to a specific space using the communication portion **490**. For example, educational materials can be fed from a classroom of a school, a university, or the like, and displayed to be used as a schoolbook. Alternatively, materials distributed from a conference room in, for example, a company, can be received and displayed (see FIG. **16**C).

Embodiment 6

In this embodiment, a display module and electronic devices which include a display panel of one embodiment of the present invention will be described with reference to FIGS. **18**A to **18**H.

FIGS. **18**A to **18**G illustrate electronic devices. These electronic devices can include a housing **5000**, a display portion **5001**, a speaker **5003**, an LED lamp **5004**, operation keys **5005** (including a power switch or an operation switch), a connection terminal **5006**, a sensor **5007** (a sensor having a function of measuring force, displacement, position, speed, acceleration, angular velocity, rotational frequency, distance, light, liquid, magnetism, temperature, chemical substance, sound, time, hardness, electric field, current, voltage, electric power, radiation, flow rate, humidity, gradient, oscillation, odor, or infrared rays), a microphone **5008**, and the like.

FIG. **18**A illustrates a mobile computer, which can include a switch **5009**, an infrared port **5010**, and the like in addition to the above components. FIG. **18**B illustrates a portable image reproducing device (e.g., a DVD player), which is provided with a memory medium and can include a second display portion **5002**, a memory medium reading portion **5011**, and the like in addition to the above components. FIG. **18**C illustrates a goggle-type display, which can include the second display portion **5002**, a support portion **5012**, an earphone **5013**, and the like in addition to the above components. FIG. **18**D illustrates a portable game machine, which can include the memory medium reading portion **5011** and the like in addition to the above components. FIG. **18**E illustrates a digital camera, which has a television reception function and can include an antenna **5014**, a shutter button **5015**, an image receiving portion **5016**, and the like in addition to the above components. FIG. **18**F illustrates a portable game machine, which can include the second display portion **5002**, the memory medium reading portion **5011**, and the like in addition to the above components. FIG. **18**G illustrates a portable television receiver which can include a charger **5017** capable of transmitting and receiving signals, and the like in addition to the above components.

The electronic devices illustrated in FIGS. **18**A to **18**G can have a variety of functions, such as a function of displaying a variety of information (e.g., a still image, a moving image, and a text image) on a display portion, a touch panel function, a function of displaying a calendar, date, time, and the like, a function of controlling processing with a variety of software (programs), a wireless communication function, a function of being connected to a variety of computer networks with a wireless communication function, a function of transmitting and receiving a variety of data with a wireless communication function, and a function of reading program or data stored in a memory medium and displaying the program or data on a display portion. Furthermore, the electronic device including a plurality of display portions can have a function of displaying image information mainly on one display portion while displaying text information on another display portion, a function of displaying a three-dimensional image by displaying images where parallax is considered on a plurality of display portions, or the like. Furthermore, the electronic device including an image receiving portion can have a function of photographing a still image, a function of photographing a moving image, a function of automatically or manually correcting a photographed image, a function of storing a photographed image in a memory medium (an external memory medium or a memory medium incorporated in the camera), a function of displaying a photographed image on the display portion, or the like. Note that functions of the electronic devices in FIGS. **18**A to **18**G are not limited thereto, and the electronic devices can have a variety of functions.

FIG. **18**H illustrates a smart watch, which includes a housing **7302**, a display panel **7304**, operation buttons **7311** and **7312**, a connection terminal **7313**, a band **7321**, a clasp **7322**, and the like. The substrate which is used for the display panel **7304** is a flexible film substrate, which is light and is less likely to be broken than the glass substrate.

The display panel **7304** mounted in the housing **7302** serving as a bezel includes a non-rectangular display region. The display panel **7304** may have a rectangular display region. The display panel **7304** can display an icon **7305** indicating time, another icon **7306**, and the like.

The smart watch illustrated in FIG. **18**H can have a variety of functions, such as a function of displaying a variety of information (e.g., a still image, a moving image, and a text image) on a display portion, a touch panel function, a function of displaying a calendar, date, time, and the like, a function of controlling processing with a variety of software (programs), a wireless communication function, a function of being connected to a variety of computer networks with a wireless communication function, a function of transmitting and receiving a variety of data with a wireless communication function, and a function of reading program or data stored in a recording medium and displaying the program or data on a display portion.

The housing **7302** can include a speaker, a sensor (a sensor having a function of measuring force, displacement, position, speed, acceleration, angular velocity, rotational frequency, distance, light, liquid, magnetism, temperature, chemical substance, sound, time, hardness, electric field, current, voltage, electric power, radiation, flow rate, humidity, gradient, oscillation, odor, or infrared rays), a microphone, and the like. Note that the smart watch can be fabricated using the display module described in Embodiment 1 or 3 for the display panel **7304**.

Note that this embodiment can be combined with any of the other embodiments in this specification as appropriate.

This application is based on Japanese Patent Application serial No. 2016-059492 filed with Japan Patent Office on Mar. 24, 2016, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A method for manufacturing a semiconductor device comprising the steps of:
- forming an oxide layer over a light-transmitting substrate;
- forming a metal layer over the oxide layer;
- forming a resin layer over and in contact with the oxide layer and the metal layer;
- forming an element layer over the resin layer;
- fixing a flexible film to the element layer;
- irradiating the resin layer and the metal layer with light through the light-transmitting substrate after fixing the flexible film to the element layer;
- separating the light-transmitting substrate; and
- making a bottom surface of the metal layer bare.

2. The method for manufacturing a semiconductor device, according to claim **1**, wherein the light is emitted from a laser light source.

3. The method for manufacturing a semiconductor device, according to claim **1**,
- wherein the element layer comprises an electrode, and
- wherein the electrode is electrically connected to a top surface of the metal layer through an opening formed in the resin layer.

4. The method for manufacturing a semiconductor device, according to claim **1**, wherein the metal layer comprises any one of tungsten, molybdenum, chromium, copper, silver, gold, and nickel.

5. The method for manufacturing a semiconductor device, according to claim **1**, wherein the oxide layer comprises silicon.

6. The method for manufacturing a semiconductor device, according to claim **1**, wherein the element layer comprises a transistor.

7. A method for manufacturing a semiconductor device comprising the steps of:
- forming an oxide layer over a substrate;
- forming a metal layer over the oxide layer;
- forming a resin layer over the metal layer;
- forming a barrier layer over the resin layer;
- forming a layer comprising an element over the barrier layer;
- attaching a film to the layer comprising the element;
- performing light irradiation after side surface treatment is subjected to the substrate or a processing for cutting the substrate is performed;
- starting separation from a side surface of the substrate subjected to the side surface treatment or to the cutting processing; and
- separating the substrate,
- wherein the oxide layer is in contact with the metal layer.

8. The method for manufacturing a semiconductor device, according to claim **7**, wherein the light irradiation is performed by irradiating the resin layer with light emitted from a laser light source.

9. The method for manufacturing a semiconductor device, according to claim **7**, wherein the substrate is a light-transmitting substrate.

10. The method for manufacturing a semiconductor device, according to claim **7**,
- wherein the element comprises an electrode, and
- wherein the electrode is electrically connected to a top surface of the metal layer through an opening formed in the resin layer.

11. The method for manufacturing a semiconductor device, according to claim **7**, wherein the metal layer comprises any one of tungsten, molybdenum, chromium, copper, silver, gold, and nickel.

12. The method for manufacturing a semiconductor device, according to claim **7**, wherein the oxide layer comprises silicon.

13. The method for manufacturing a semiconductor device, according to claim **7**, wherein the element comprises a transistor.

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